# FINAL REPORT

of the

DEFENSE SCIENCE BOARD

TASK FORCE ON V/STOL AIRCRAFT

NOVEMBER 1979

Office of the Under Secretary of Defense for Research and Engineering

Washington, D.C. 20301

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

| | |
|---|---|
| 1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED | 1b. RESTRICTIVE MARKINGS: NONE |
| 2a. SECURITY CLASSIFICATION AUTHORITY: N/A | 3. DISTRIBUTION/AVAILABILITY OF REPORT: Distribution Statement A. Approved for Public Release. Distribution is unlimited |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S): N/A | 5. MONITORING ORGANIZATION REPORT NUMBER(S): N/A |
| 6a. NAME OF PERFORMING ORGANIZATION: Defense Science Board, Ofc of the Under Secy of Def (A) — 6b. OFFICE SYMBOL (If applicable): DSB/OUSD(A) | 7a. NAME OF MONITORING ORGANIZATION: N/A |
| 6c. ADDRESS (City, State, and ZIP Code): The Pentagon, Room 3D1020, Washington, D.C. 20301-3140 | 7b. ADDRESS (City, State, and ZIP Code): N/A |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Defense Science Board/OUSD(A) — 8b. OFFICE SYMBOL (If applicable): DSB/OUSD(A) | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N/A |
| 8c. ADDRESS (City, State, and ZIP Code): The Pentagon, Room 3D1020, Washington, D.C. 20301-3140 | 10. SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO |
|---|---|---|---|
| N/A | N/A | N/A | N/A |

11. TITLE (Include Security Classification)
Final Report of the Defense Science Board Task Force on V/STOL Aircraft, UNCLASSIFIED

12. PERSONAL AUTHOR(S)
N/A

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| FINAL | FROM N/A TO N/A | 79/11/00 | 88 |

16. SUPPLEMENTARY NOTATION
N/A

| 17. COSATI CODES | | | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) |
|---|---|---|---|
| FIELD | GROUP | SUB-GROUP | |
| | | | |
| | | | |

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

| | |
|---|---|
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS | 21 ABSTRACT SECURITY CLASSIFICATION |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL: Diane L.H. Evans | 22b TELEPHONE (Include Area Code): (202) 695-4158/6463 — 22c OFFICE SYMBOL: DSB/OUSD(A) |

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

**OFFICE OF THE SECRETARY OF DEFENSE**
**WASHINGTON, D.C. 20301**

**DEFENSE SCIENCE BOARD**

1 December 1979

Honorable Harold Brown
Secretary of Defense
Pentagon, Room 3E880
Washington, D. C. 20301

Dear Harold,

The executive summary is so short that I don't believe I need to "gist" it. Let me simply note that we have spent several years worrying about whether or not we could develop a supersonic, high performance V/STOL aircraft that could replace Navy, and perhaps Air Force, high performance CTOL aircraft. According to this report, our priority has been wrong. If we accept the fact that we need a nucleus of CTOL high performance aircraft (and the carriers and airfields they require) in order to maintain air superiority and a heavy load strike capability, then subsonic V/STOL aircraft added to these forces will increase the size of the strike force while at the same time the whole force would be more flexible and survivable, beginning in the mid 1980s. The Task Force concludes that our priorities should be adjusted so that we no longer look for a V/STOL to replace CTOL, but rather we seek an optimum CTOL-V/STOL mix, beginning in the mid 1980s. Technology and strategy will probably dictate an evolution toward a higher V/STOL mix, including high performance supersonic types by the year 2000, and we should invest in being prepared to support that.

The subsonic V/STOL support aircraft could be an important part of the extended horizon $C^2$ support for ships and units not having direct support from a large carrier or air base. The subsonic V/STOL combat aircraft could be another important way to distribute our offensive force, and to provide increased capability to strike the type of dynamic target which the cruise missile cannot strike.

I believe that we need to get V/STOL aircraft into an operational status in the Navy and Air Force, as well as the Marine Corps. Only then will we be able to fully understand their potential.

Sincerely,

Gene

Eugene G. Fubini
Chairman

Attachment

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

20 NOV 1979

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Task Force on V/STOL Aircraft

The subject report is forwarded, fulfilling the charter provided by the Under Secretary of Defense for Research and Engineering. The main conclusions are contained in the Executive Summary. The Task Force concludes generally that V/STOL aircraft in various subsonic and supersonic configurations are technologically supportable over the next several decades. Perhaps more importantly, the Task Force benefited from active participation of all of the Services, and saw strong support for V/STOL aircraft in useful military missions. The front-end investment may be high, however, the pay-off is considered to be potentially in excess of that investment.

Thank you for the opportunity to chair this Task Force. It has been a rewarding endeavor which I trust will be of benefit in making important decisions on our future military and naval forces.

Courtland D. Perkins
Chairman
DSB Task Force on
V/STOL Aircraft

## CONTENTS

DEFENSE SCIENCE BOARD

Task Force on V/STOL Aircraft

## Background

At the request of Dr. William Perry, Under Secretary of Defense for Research and Engineering, a Task Force of the Defense Science Board (DSB) was organized to review the status of V/STOL technology and to seek out new concepts and V/STOL capabilities. The Terms of Reference is included as Appendix A.

The major thrust of this study was to examine the state of the art in the various technologies that support V/STOL capabilities, the projection of these technologies into new configuration possibilities with improving performance potential, and to measure against them the emerging operational concerns of the Armed Services in the expectation that military weapons possibilities will be improved.

The first phase of the Task Force (conducted in 1978) focused on technology. The second phase of the Task Force had two meetings to develop background in the matching of technology with missions; one was on 10 April and the second on 13 June 1979. Both meetings were held at the National Academy of Sciences (NAS) building in Washington, D.C. A final five-day meeting of the Task Force was held at the NAS Summer Study Facility at Woods Hole, Massachusetts from 25-29 June 1979. This report covers the conclusions arrived at as a result of these meetings and is presented to the Chairman, DSB and Dr. Perry as fulfilling their basic charge.

This report is presented in two sections. One deals with the mission concerns of the Army, Navy, Air Force and Marines, and how they might be resolved through the application of modern V/STOL capabilities. The second section deals with new V/STOL concepts that have emerged as the result of this advancing state of the art. Real operational concerns and viable V/STOL solutions are identified.

The Terms of Reference for both phases of the study are provided as Appendix A. The agenda for Task Force meetings are included in Appendix B. Sample supporting data presented to the Task Force is provided in Appendix C.

The Committee that coordinated this study and developed the report included the following:

Dr. Leonard Roberts
NASA Ames Research Center

Dr. Leland D. Strom
Delphi Corporation

Mr. Richard E. Kuhn
Newport News, VA

Mr. Charles E. Myers
Aerocounsel, Inc.

Mr. E. C. Simpson
Wright-Patterson AFB

Professor David C. Hazen
Princeton University

Professor Jack L. Kerrebrock
M. I. T.

Admiral James H. Holloway, USN (Ret.)
Arlington, VA

Mr. J. J. Welch, Jr.
Vought Corporation

Professor James W. Mar
M. I. T.

Dr. Norman Grossman
Fairchild Republic Co.

Dr. Courtland D. Perkins, Chairman
National Academy of Engineering

Cdr Robert C. Powers, USN, Exec. Sec.
Defense Science Board

## Executive Summary

### V/STOL Status

The only V/STOL aircraft operational today are the helicopter and a subsonic combat aircraft of British design, the AV-8A Harrier. The unique capability of the helicopter is of such importance to the Armed Services that it is widely used despite its relatively poor performance in terms of range, speed, maintainability and operating cost compared to fixed wing aircraft.

The Harrier is now employed by the RAF, the Royal Navy Air Arm and the U.S. Marines as a partial solution to the problem of dispersal of land-based tactical aircraft and to provide increased operational flexibility for sea-based aircraft.

The AV-8B, an improved version of the Harrier is now being tested and represents a significant improvement. In the STOL mode, it is competitive with CTOL combat aircraft of its size, and it retains the flexibility of V/STOL with adequate payload capacity. The AV-8B has demonstrated its ability to use a "ski-jump" STOL takeoff which provides increased payload using a short runway.

Advances in the technology associated with engines, structures, control systems and avionics, in conjunction with the emergence of new configurational concepts, have reduced the penalties in cost and performance that have traditionally attended V/STOL aircraft. Subsonic V/STOL aircraft with useful payloads are a reality for the 1980s. Low supersonic V/STOL aircraft could be available in the 1990s, and high performance supersonic V/STOL aircraft could be operational by the year 2000.

### Mission/Technology Matching

In light of both needs and the availability of technology, the pattern that emerges for V/STOL aircraft is as follows:

1. Subsonic support aircraft are needed by the Navy and can be developed through the use of existing technology in the near term, i.e., the 1980s.

2. Subsonic combat aircraft are needed by the Marines, the Navy and the Air Force. STOL versions can evolve from existing configurations with little compromises in performance, during the 1980s. VTOL versions beyond the Harrier could also be developed but will continue to have lower than conventional range and payload capability until further technology is provided.

3. Supersonic combat aircraft will be needed by the year 2000 and will depend on technology developments that are not currently available. This technology will result only if a sustained effort is undertaken over the next decade.

### General Conclusions and Recommendations

The following conclusions and recommendations have general applicability to all of the Armed Services.

(cont'd)

Conclusions

1) The ability of the ~~Military Services~~ to conduct their respective missions can be enhanced by the timely introduction of V/STOL aircraft. The number of potential mission improvements, coupled with the need for increased survivability and operational flexibility, provides a convincing case for the accelerated development of an enhanced V/STOL capability.

2) The technology will currently support significant improvements in those aircraft configurations that are not radical departures from existing classes of V/STOL aircraft, notably variants of the helicopter and of the subsonic combat aircraft, the Harrier. and

3) V/STOL combat aircraft of modest subsonic capability could also evolve; however, substantial technology investments must be made in order to permit a completely new high performance supersonic V/STOL combat aircraft. (edc)

Recommendations (in order of priority)

It is recommended that:

1. Each of the Armed Services be requested by the Office of the Secretary of Defense to determine which of its missions can benefit from an enhanced V/STOL capability and to concentrate a suitable portion of its R&D resources on a specific technology development and demonstration program that assures rapid progress toward this capability. An effective mechanism for coordinating these efforts with each other and with related efforts in NASA should be established by the Office of the Secretary of Defense.

2. In an overall program of V/STOL technology development, particular attention should be given to the following:

   a. Improvements in vectored thrust aircraft design that will result from advances in engine technology, control system technology, the use of composite structures and careful integration of the airframe and propulsion system. (Including in-flight thrust vectoring for maneuverability.)

   b. Technology demonstration of an integrated fault tolerant engine/airframe control system for V/STOL aircraft.

   c. A lift-engine program that will provide the necessary technology by 1985 to support future engine developments.

Specific Conclusions and Recommendations

The following conclusions and recommendations are applicable to the appropriate Military Service as indicated below:

U.S. Navy

Conclusions

1. The Navy must develop V/STOL aircraft in conjunction with appropriate surface ships and weapon systems in order to be effective in the threat environment through the year 2000 and beyond.

2. It is likely that a high-altitude high-speed (subsonic) V/STOL aircraft configured for the AEW, ASW and missileer roles will produce the most immediate increase in capability, possibly by 1990. Such an aircraft could be used in conjunction with the larger carriers and with a new class of smaller carriers, and would be of great value in providing noncarrier task groups with an "eye-in-the-sky". The technology for such an aircraft currently exists but requires flight demonstration at the earliest opportunity.

3. It is not yet clear whether a low-altitude low- speed V/STOL aircraft such as the Tilt Rotor or the ABC will provide a sufficiently increased capability, beyond that provided by the helicopter, to justify development by the Navy. Demonstration of the technology for these variants of the helicopter should continue, if possible.

4. A supersonic V/STOL replacement of the F14/F18 mix will be required and will be a particularly valuable asset after the year 2000 as the large carrier task force is reduced. Extensive technology efforts are required, in the area of airframe, propulsion, control system integrated design for the horizontal attitude configurations, and in the area of the aircraft, pilot, ship interface for vertical attitude configurations, before such a replacement is feasible.

Recommendations (in order or priority)

It is recommended that:

1. The Navy concentrate its currently meagre V/STOL R&D resources on a smaller number of concepts and on a few specific technology development and demonstration activities:

   a. Give priority to the demonstration of a high-altitude high-speed (subsonic) V/STOL aircraft utilizing existing components (for example, the S3A airframe and the Pegasus engines) that would serve as a technical reference point and provide for the in-flight evaluation of future aircraft concepts (i.e., AEW, ASW, missileer in this class).

   b. Complete the evaluation of the helicopter derivatives (i.e., Tilt Rotor and ABC) and Harrier derivatives (AV-8B) including in-flight investigations in the ship environment.

   c. Terminate the Thrust Augmented Wing (TAW) Program. It is unlikely that the present configuration will lead to an operationally useful aircraft or produce sufficiently new technical information to justify the expense of a continuing program.

   d. For the X-wing concept, emphasize ground-based investigations aimed at understanding the dynamic behavior and performance of the rotor system at a scale more representative of a mission article.

2. The Navy give serious consideration to building a V/STOL support ship (VSS). Such a ship would be a valuable asset with currently available aircraft and would provide the means to develop V/STOL aircraft and V/STOL specialized platforms in parallel. This ship could employ an AV-8 derivative, a missileer

aircraft, surveillance aircraft and helicopters. With the introduction of high-altitude, high-speed subsonic support aircraft for ASW or AEW missions, along with the potential available through the development of new concepts such as SLAT and SOJM, such a vessel would be able to conduct independent military operations across the full spectrum of naval warfare (but not replace large carrier capability).

3. As a longer-term continuing effort, the Navy should conduct both mission related studies and technology programs to better understand the role of advanced V/STOL aircraft in future Naval operations:

   a. Conduct studies involving a spectrum of vessel, aircraft and weapon concepts including supersonic fighters, SLAT concepts, the VSS and other ships, to provide guidance in the development of future force structures.

   b. Consider V/STOL designs that do not require engine-out vertical landing capability but instead depend on increased engine and control system reliability (including escape system reliability) to achieve safety and mission success.

## U.S. Marine Corps

### Conclusion

The Marine Corps has well-defined mission requirements for both V/STOL subsonic combat aircraft such as the Harrier AV-8B and for helicopter or helicopter-derived support aircraft. When high performance supersonic combat aircraft become available they will greatly enhance the Marine Corps' concept of operations.

### Recommendations (in order of priority)

It is recommended that:

1. Procurement of the AV-8B should proceed, to permit a complete evaluation of advanced STOL and STOVL operations.

2. The Marine Corps continue to build on their operational experience with V/STOL aircraft and continue to evolve and refine operational concepts, support systems and $C^3$ arrangements for operations from dispersed sites.

## U.S. Air Force

### Conclusions

1. An immediate need for the Air Force is to develop the ability to operate from damaged runways or dispersed sites where takeoff and landing distances may not exceed 1500 to 2000 feet. Although V/STOL aircraft may be an eventual requirement, STOL aircraft having balanced field performance (such as ability to take off and land on a sod field) deserve early attention.

2. Operation from dispersed sites will involve new methods of logistic and maintenance support, the development of a resilient and flexible $C^3$ system, and the introduction of a new air distribution system employing such aircraft as the AMST.

Recommendations (in order of priority)

1. The Air Force undertake a thorough examination of STOL and STOVL technology as it relates to the design of combat, support and transport aircraft in the context of the European airbase vulnerability problem, including:

   a. An evaluation of the AV-8A and AV-8B as a STOVL aircraft, and its use as a means of assessing the logistic, maintenance, command and control problems associated with the operation from dispersed sites.

   b. A study of existing powered lift technology and its possible use in the modification of current combat aircraft to permit their deployment from short runways. (We should also look at modifying current aircraft landing gear to be able to use sod field.)

   c. A review of the role of the AMST or improved versions as a logistics aircraft capable of operation from runways of 1500-2000 feet in length.

   d. An assessment of the necessary technology in aerodynamics, propulsion and control systems that would permit the introduction of a new generation of supersonic STOL and STOVL aircraft during the 1990s.

## U.S. Army

### Conclusion

V/STOL aircraft, other than helicopters, appear to be generally incompatible with Army missions, due to their higher downwash and poor hovering efficiency.

Recommendations (in order of priority)

1. The heavy lift helicopter technology program should be strengthened, if necessary, in light of the potential need for this capability in the NATO theater and elsewhere.

2. A clearer rationale for Army interest in the ABC and the Tilt Rotor, should be developed, recognizing that these programs primarily address the technology for rotorcraft having speeds in excess of 300 mph.

## Introduction

The quest for higher and higher performance military aircraft has, over the past several decades, led inexorably to the need for longer and longer runways to accommodate land based aircraft and to larger and more sophisticated carrier decks for sea based aircraft including the use of angled decks, catapults and arresting gear. The complexity of the bases and the dependence upon sophisticated support systems for full mission capability has made tactical air operations vulnerable to a growing spectrum of counter-air weaponry.

Main operating air bases and aircraft carriers are prominent, unconcealable, easily targeted and subject to attack from a variety of long range weapons. The problem is aggravated by the accepted rule that only the enemy has the option of initiating hostilities, thus we must accept, and absorb, the first blow.

Key elements of the bases are the runways and taxiways of the airfields and the decks, catapults and arresting gear of the carriers. There has been a growing feeling among our military thinkers that dependence upon these elements must be reduced if tactical air power is to remain a viable and meaningful factor in modern warfare. The need to operate from damaged runways or carrier decks as well as the possibility that it may prove desirable to disperse aircraft among larger numbers of smaller fields or ships has provided renewed interest in the requirement for vertical or short take-off and landing aircraft. Such machines fall into the broad aeronautical field referred to as V/STOL covering many technical possibilities with many different tradeoffs. V/STOL has been a technical capability of interest for many years, but except for a very few cases, this interest has been developed primarily by technologists rather than military operators.

During the past few years several things have happened to make V/STOL capability more attractive to the operators. The first is that the technologies in engines, structures, stability and control and avionics have all been improving rapidly making the cost differential in performance, maintainability, and dollars between a V/STOL design and conventional takeoff and landing, or CTOL, design less severe. The second is that the facts of operational life make it important that all branches of the Armed Services consider seriously takeoff and landing operational requirements. This new concern of the four Services is the major rationale for this study. How serious are these concerns? What can technology do today to resolve some of these operational problems? Do we have an adequately funded research and development program focused on the important elements of these states of the art? And what steps should be taken to introduce some of these important new capabilities into the operational forces? These were the factors addressed by the DSB task force, and it is hoped that this report may shed some light on possible solutions to these questions.

V/STOL is an old subject that has generated great enthusiasm, particularly in the technical community, over many years. There have been many studies such as this one. The first for the Department of Defense was undertaken in 1959 for Dr. Herbert York, then Director of Defense Research and Engineering (DDR&E). This study group upon reviewing V/STOL technology and service requirements recommended the development of a V/STOL logistic aircraft that could carry a six-ton payload. It was a tilt-wing turboprop, considered by a majority of the technical community of that day as perhaps the most feasible solution. A

prototype program was initiated supported on a tri-Service basis (Army, Navy and Air Force); the program involved the construction of five airplanes designated the XC-142 for operational testing. Four of these aircraft flew and proved (a) that the technology wasn't quite as ready as the enthusiasts believed, (b) that an airplane with a vertical takeoff and landing capability would about double its payload if allowed a short (500') ground roll and, most importantly, (c) none of the three Services were really interested in the airplane--they didn't want to pay the additional cost for this V/STOL over an equivalent CTOL, in dollars, handling qualities or complexities. A number of operational capabilities peculiar to V/STOL were demonstrated in the XC-142 program. However, these capabilities were not judged to be sufficiently attractive at that time to offset the cost penalties associated with V/STOL capability. One remaining XC-142 rests in the Air Force museum at Wright Field.

A second serious V/STOL program that got further than a study phase was the cooperative effort between the United States Air Force and the Federal Republic of Germany, the US/FRG program. This was a fighter development that asked for everything. Its motivation was dispersal and focused on the intercept and the ground attack missions. The airplane was to have supersonic capability and was designed around the lift plus lift/cruise engine concept. This program went far down the development road, including wind tunnel tests and much detail design, but was ultimately cancelled. Its major difficulties were that (a) the USAF operators didn't really feel that dispersal, as envisioned at that time, was essential, (b) the lift plus lift/cruise engine concept was complex and resulted in much operational complication, and (c) the single engine-out requirement that called for an ability to prevent out-of-control rotation subsequent to the loss of an engine resulted in a massive configuration involving four retractable lift engines and two lift/cruise engines.

There have been many other V/STOL development projects involving a myriad of concepts--these include tail sitters or chin hangers, the so called Vertical Attitude Takeoff and Landing (VATOL) aircraft, as well as helicopters, compound helicopters, tilt wings, tilt rotors, fan in wings, flow augmentation systems, lift plus lift/cruise, and many others. The only V/STOL configurations that have made it into operations have been the pure helicopters and, more recently, the medium bypass turbofan vectored thrust arrangement. The helicopters can provide direct VTOL capability for the least horsepower and downwash. This capability is contributing to all military services and to the commercial world as well. It is a capability of such importance, that the limitations of the helicopter--low speed, poor range, and marginal maintainability--are acceptable when measured against what it can do. The pure helicopter has been developed today to a point where its deficiencies have been minimized within the limits of current technology. Attempts to increase helicopter performance capabilities further have resulted in higher costs and complexities, increased downwash, and in some cases decreases in safety.

The only other type of V/STOL aircraft operational is the British designed Harrier or AV-8A. This aircraft and its follow-on version, the AV-8B, has been under development for about 25 years and has resulted in a reliable aircraft with a real military capability. It is a single engine vectored thrust configuration that can take off vertically with a reasonable payload, can improve this payload significantly with a short ground roll, and perform ground support missions of significance. The U.S. Marines, the Royal Air Force and the Royal Navy Air Arm are all being equipped with these aircraft as a solution to the

dispersal problems of the land based aircraft and for increased carrier operational flexibility for sea based versions. It has been demonstrated that for a given takeoff roll the range payload characteristics of the AV-8A and B can be significantly increased through the use of an angled ramp or "ski jump".

To deal with this myriad of concepts with which the V/STOL field abounds, it is useful to develop a scale by which the maturity of the technology involved may be judged. The least mature may be termed a "demonstrable phenomonology". At this stage of evolution, the existence of a physical phenomenon has been demonstrated, frequently only at model scale, but many questions about scaling effects, mechanical complexity, and the like, remain unanswered. All of the concepts reviewed by the Task Force had passed this stage.

The next level of technological maturity may be described as "demonstrable feasibility". Many of the V/STOL concepts under study at present fall into this category. Generally this involves the existence of extensive full scale test data of critical elements of the concept, sometimes assembled in actual V/STOL aircraft components, perhaps even flown as a proof-of-concept test bed, but frequently merely extrapolated from conventional aircraft practice. There remains a considerable developmental risk at this point, because experience has shown that there are inevitably many unexpected practical difficulties encountered when one tries to assemble the various elements of anything as complex as a V/STOL aircraft into an operational whole.

The third level of maturity is reached when operational feasibility has been demonstrated. At this point the various elements of the concept have been assembled into an aircraft seriously intended for operational service which has undergone extensive developmental flight testing. Although the machine in question may well be a production prototype and the test program has fully explored its handling qualities and performance characteristics there is still much to be learned about the practical operational realities of realiability and maintaininability. The Tilt-Rotor and Advancing Blade Concept (ABC) machines are at about this stage.

Full maturity of the technology is achieved only after it has been applied to operational aircraft for a sufficient period of time that experience has been gained with all of the practical aspects of the factors required to maintain satisfactory operational levels. For military aircraft this includes the evaluation of operational concepts and doctrine as well as the development of maintenance and logistic procedures. The AV-8A and B were the only V/STOL aircraft reviewed by the Task Force that had achieved this level of technological maturity.

It has taken roughly 25 years and four generations of aircraft, the P-1127, the Kestrel, the Harrier, and now the AV-8B, to bring the single engine vectored thrust technology to this state of maturity, partly because of the state of the art and partly because of lack of military operator interest in the V/STOL capability at what was deemed by many to be an unacceptable cost in performance and complexity. The questions addressed by this study were first whether or not the various technologies basic to airplane design have improved sufficiently to make the cost of V/STOL more acceptable to missions other than those solved by the helicopter and the Harrier, and second, the degree to which the military requirements are altering the face of the changing threat in manners that make V/STOL capability more urgent.

The results of this study are presented in two parts. Part I summarizes the potential impact of new V/STOL capabilities on the operational missions of the four Services--the Army, Navy, Air Force and the Marine Corps--and suggests where each Service development interests should be centered. In Part II, the state of the art of the various technologies, basic to new V/STOL capabilities are reviewed and recommendations made as to where major Service interests should be concentrated to support further improvements in V/STOL capabilities.

## General Conclusions

It can be demonstrated that there are many missions in which the existence of various types of V/STOL aircraft can significantly enhance the capability of the military Services in carrying out their respective missions. Most of these are, however, also susceptible to various other solutions, and none that the Task Force considered, so demonstrably uniquely improved by V/STOL as to absolutely demand its adoption. On balance, however, it is the large number of potential mission improvements coupled with the need to increase survivability and flexibility that builds the convincing case for continued consideration and development of a V/STOL capability.

A variety of compelling arguments exist for the Navy to develop a spectrum of V/STOL capabilities in order to operate surface ships in the threat environment of 2000 and beyond. To do this most effectively an integrated development of ship, plane and weapons will be required.

It appears likely that the high-altitude high-subsonic speed V/STOL, configured for the AEW, ASW or missileer roles--possibly coupled with new missile concepts--mated both with the CTOL air groups of the big carriers and with a new class of smaller vessels (VSS) will produce the most immediate increase of capability, possibly by 1990.

Eventual introduction of a supersonic V/STOL replacement for the F-14/18 mix will be required. Current technology is not mature enough to support such development, but with appropriate levels of effort, could make such aircraft available by 2000 as the large deck carrier force begins to reduce.

The Marines have well-defined mission requirements for a high-altitude high-subsonic speed combat aircraft such as the AV-8B. As high performance supersonic combat aircraft with V/STOL capability become available they will greatly enhance the Marine Corps concept of operation. It appears the rest of the Corps V/STOL requirements are best met by low disc loading machines like helicopters.

Mission analyses show the greatest immediate need for the Air Force is the development of the ability to operate from damaged runways or dispersed sites where takeoff and landing runs may only be of 1500 to 2000 feet in length. V/STOL machines may be of eventual interest, but current attention must be focused on achieving STOL balanced field performances from the existing fleet of aircraft.

The Army has little need for V/STOL aircraft other than helicopters.

The maturity of certain V/STOL technologies, particularly those associated with the moderate by-pass vectored thrust engine, and the Tilt Rotor, have developed to the point where successful and useful aircraft can be constructed and operated.

Certain other technologies of interest are less mature, particularly lift engines and various thrust augmentation arrangements which may be of concern in the development of high performance supersonic aircraft, and extensive technology effort is required.

The general areas of flight control and handling qualities criteria, for all forms of V/STOL aircraft require more study, including the possibility of relieving the pilot of some work load by making use of ground based systems.

On balance, however, the current state of V/STOL technology will permit the immediate development of high-altitude, high-subsonic speed combat aircraft with useful military capabilities. The development of high-altitude high-subsonic speed support aircraft will take slightly longer, probably involving the intermediate development and testing of a flight demonstrator, before committing to production prototype design.

High confidence can also be placed in the technological support of low-altitude low-subsonic speed designs such as the Tilt Rotor or ABC designs, but the mission requirements for such machines are far from clear.

V/STOL aircraft with moderate supersonic capability (i.e., M = 1.5-1.6) could probably be evolved within five years from the moderate by-pass technology by making use of plenum chamber burning or similar schemes. Because of the airframe shape compromises required by such concepts it is not clear that sufficiently high performance can be achieved to warrant the developmental effort.

Of all potential supersonic configurations it is likely that VATOL machines require the least extension of existing technology and offer the greatest performance for the least penalty. There are, however, obvious reluctances to overcome before such operational modes will be generally accepted. Ground support equipment also poses restraints on operation. The concept, however, warrants further study.

Of the HATOL configurations, probably the lift plus lift/cruise design is the most mature from an airframe point of view. Lift engine availability is the pacing factor to such designs, probably implying that the earliest IOC will be approximately ten years in the future.

V/STOL designs of the past have all suffered from the imposition of engine performance ratings and qualification programs, engine-out and fuel reserve requirements which are based on CTOL experience and are not realistic for machines with operating profiles such as those under consideration. Given available flight experience, such requirements should be reconsidered.

## Specific Conclusions and Recommendations

### U.S. Navy

The Navy should concentrate the currently meagre V/STOL R&D resources on a smaller number of subsonic V/STOL concepts and on a few specific technical advances that contribute most to the success of these concepts. Full technical readiness regarding decisions for the development of subsonic support and combat aircraft could be achieved by 1985 if some additional funds are made available over the next five years.

To advance the maturity of the technology of high altitude high speed subsonic support aircraft, early flight demonstrators of the two most promising concepts, one using Pegasus engines the other lift/cruise fan engines should be built, in a cooperative effort with NASA, and extensively tested in a manner similar to the Tilt Rotor and the ABC.

In future design competitions for VTOL capable aircraft, configurations without engine-out landing capability should be considered, given reasonable assurance of the avoidance of upsetting moments in the event of engine failure.

The current Thrust Augmented Wing program should be terminated. The present configuration will not produce an operationally useful aircraft, nor will additional testing provide sufficient new technical information to warrant the expense.

To avoid repeating the errors of the TAW program, effort on the X-wing concept should be concentrated on understanding the dynamic behavior and performance of the rotor system at a scale more representative of a mission article (i.e., typically a 50 foot diameter rotor) using ground facilities, and the trade-off between performance and complexity of the propulsion system before further consideration is given to the funding of a subscale flight article.

As a longer term effort, the Navy should continue to study a number of supersonic V/STOL concepts including both HATOL and VATOL configurations in order to determine which of these hold promise.

Operational studies involving a spectrum of vessel, aircraft and weapon concepts including supersonic fighters, missileers, SLATs, the VSS and others should be conducted to provide guidance in the development of future force structures.

### U.S. Marine Corps

As the Service with the greatest operational experience with V/STOL aircraft, the Marine Corps should continue to evolve and refine operational concepts, support systems and $C^3$ arrangements for operations from dispersed sites.

Even though by initiating a new design employing advanced technology throughout, it should be possible to develop an aircraft with considerably better performance than the AV-8B, the capability provided by the B model is significant, and provides a better basis for judging the operational worth of V/STOL concepts than the very limited AV-8A. To the extent possible, without jeopardizing the

Navy's efforts to maintain the carrier force as the viable factor it must remain through the turn of the century, funds should be provided so that the aircraft can be procured, if only in limited numbers, to permit an evaluation of advanced STOL and STOVL operations.

U.S. Air Force

The U.S. Air Force should undertake a thorough examination of STOL and STOVL technology as it relates to the design of combat, support and transport aircraft in the context of the European airbase vulnerability problem.

A study should be made of existing powered lift technology with an eye to modification of current U.S. combat aircraft in order to permit their deployment from 2,000 foot runways during the 1980s.

The AV-8A/B should be employed to evaluate the logistic, maintenance and command and control problems associated with dispersed operations from small fields.

The potential role of the AMST as a logistics aircraft capable of operation into 2,000 foot runways should be reviewed to determine whether further technological improvements are necessary.

The AV-8B should be evaluated as a STOVL aircraft operated from 2,000 foot runways to determine whether further technological improvements can result in range/payload capabilities compatible with U.S. Air Force needs for the 1980s.

Identify and pursue the necessary technology program in aerodynamics and propulsion to permit the introduction of a new generation of subsonic support aircraft and supersonic combat aircraft for the 1990s capable of operations from dispersed sites. STOL, V/STOL and VATOL solutions should be evaluated.

U.S. Army

The U.S. Army should review its programs for heavy lift helicopter technology and for high speed rotorcraft technology in the context of its future mission needs which appear to place greater emphasis on lifting capability and low downwash velocities than on forward speed.

The heavy lift helicopter technology program should be strengthened in light of the potential need for heavy vertical lift capability in the NATO theater and elsewhere.

A clearer rationale for Army interst in the Tilt Rotor and ABC concepts is required, recognizing that these programs primarily address the technology for rotorcraft having speeds in excess of 300 mph.

NASA and the Services should work closely in the pursuit of the technology programs listed below:

- A technology program should be instituted to determine the extent to which the vectored thrust concept can be improved through the introduction of advanced engine technology, advanced control system technology, further use of composite structures, and refinements in airframe-propulsion-control integration for both high-subsonic and low-supersonic combat aircraft configurations.

- A broad study and technology effort should be pursued for the next several years in cooperation with NASA, industry and the universities, to identify the most promising configurations for subsonic and supersonic V/STOL combat aircraft, and an evaluation made of the prospects of successfully developing the preferred configurations by the year 2000.

- The feasibility of an integrated fault-tolerant engine-airframe control system for VTOL should be assessed by means of technology demonstration.

- A lift engine technology program should be initiated within the context of ATEGG-APSI to provide advanced technology for a lift engine requirement in the 1985 time period.

- Review the Tilt Rotor and ABC flight programs to determine what further technological and operational information can be gained.

# PART I

## Missio

A major part of the study was an examination of the operational concerns of the four Services; Navy, Marines, Air Force and Army, and a projection of those areas in which the use of V/STOL aircraft and/or special launch platforms would significantly enhance their ability to conduct operations in the performance of their assigned missions during the time period extending past the year 2000.

In carrying out this analysis of the various mission areas in which V/STOL aircraft could be of assistance to the Armed Services in performing their functions in the threat environment projected for the 1990-2010 time period, it was convenient to consider them in several general categories without initially concentrating on specific configurations. The categories considered were:

(1) Low-speed low-altitude support aircraft (subsonic)

(2) High-speed high-altitude support aircraft (subsonic)

(3) Combat aircraft (subsonic)

(4) Combat aircraft (supersonic)

(5) Special purpose machines (specifically heavy lifters)

These categories were sufficiently distinctive in their characteristics that it seems unlikely that any two could be combined into a single multimission aircraft--with the possible exception of the two subsonic support machines, the functions of which could possibly be combined depending to some extent upon the directions taken by weapon development during the period of interest.

Consideration was given to the operational requirements for various landing and takeoff capabilities. The modes considered were:

a) Vertical Take Off and Landing (VTOL)

b) Vertical or Short Take Off and Landing (V/STOL)

c) Short Take Off and Vertical Landing (STOVL)

d) Short Take Off and Landing (STOL)

Not all aircraft generally considered under this V/STOL rubric have the same capability of performing these various maneuvers; indeed, some may not be able, nor need to, perform one or more of them at all. Since this can have a profound effect upon the configuration of the machine selected, it seemed important to establish those cases where mission requirements specified specific capabilities.

The potential contributions of V/STOL capabilities to the four Services are summarized as follows:

Navy

Although traditionally oriented toward the use of land power, in the past decade the USSR has made spectacular progress in the evolution of a balanced naval force specifically designed to challenge the U.S. Navy in the role of assuring general maritime superiority for this nation and its allies. In the development of this force the Soviets have concentrated on systems of ships, planes, weapons and supporting arrangements for surveillance, targeting and $C^3$ designed to attack and neutralize the U.S. carriers, recognized as the key elements of our offensive naval power.

There is no sign that this naval build-up is slackening. Although dropping somewhat in actual numbers, the Soviet Navy is concentrating on increasing the capabilities of its individual units evolving a force from one originally designed to support the flanks of a land action, to one designed, like ours, to project power abroad. Early pioneers of the antiship cruise missile (ASCM), the Soviets have continued to innovate, combining these weapons with long range land based strike aircraft. Recently V/STOL carriers have permitted the Russian Navy to experiment with sea based airpower. Larger carriers are expected, as are strike cruisers and faster, deeper diving submarines.

By the 1990-2000 time period of concern to this study it can reasonably be expected that the Soviets will have in place a space surveillance system that will provide essentially real time information on the locations of all U.S. surface combatants, particularly the carriers; will have continued to expand their robust and redundant $C^3$ system that has already displayed the ability to support coordinated worldwide maneuvers; and will have added additional weaponry to the naval arsenal capable of striking at surface targets three or more hundreds of miles distant. The U.S. Navy will, in short, be confronted by the most formidable threat it has had to face since before World War II.

At the present moment, it has to face this threat with a fleet that has numerically fallen to pre-World War II levels and which in the face of escalating costs and budget constraints will be hard pressed to retain even these numbers. As a result of a modernization program, the capabilities of the individual naval units have been significantly upgraded since the end of the Vietnam conflict, but the margin of superiority over the Soviet Navy has seriously eroded.

It is clear to our naval leaders that if we are to meet our national commitments the trends of the past decade must be reversed. The dilemma is how this can be accomplished without further sacrifices of current capability in order to afford the investment in future abilities given the staggering costs involved in the development of modern weapon systems. It was in this context that the Task Force examined the potential impact of V/STOL upon naval operations of the future.

Even though it is difficult to operate and maintain aircraft in small numbers at isolated sites, the employment of LAMPS helicopters from destroyer sized vessels appears to have been a qualified success. There is a considerable tactical advantage to be gained by extending the range of the ships' antisubmarine warfare (ASW) capabilities well beyond that of its own onboard sensors and weapons. Additionally, the use of such helicopters as remote radar or communication relays provide the ship with useful cover and deception possibilities even in an age of spaceborne surveillance systems.

The Task Force discussed at some length whether or not an improved low-speed low-altitude support aircraft such as the Tilt Rotor or ABC would significantly improve the capability of the air systems aboard these ships. Although there was a clear gain in the speed with which a sonobuoy field could be laid or a contact prosecuted, there was some loss in hovering efficiency in deploying and recovering certain sensors as well as in search and rescue or replenishment missions which are important corollary functions of these machines. On balance, it appeared that the largest operational gains would be obtained by emphasizing reliability and maintainability of light disc loading machines, combined, if possible, with increased speed and range.

The next question addressed was what advantages might accrue as the result of the use of V/STOL aircraft in conjunction with CTOL machines aboard the existing carriers. Here the balance had to be struck between constaints placed upon aircraft performance by VTOL operations and the constraints placed upon the carrier and its battle group by the operation of CTOL aircraft. These constraints, the need to head into the wind to launch or recover the necessity of respotting decks between flight operations, are real and significant. The ability of a VTOL machine to take off and land from effectively any spot on the flight deck without interference to the ships' progress can provide an important tactical advantage.

In all probability the greatest operational flexibility will be obtained with aircraft that have STOL capabilities as well as the essential ability to be launched and recovered vertically. Because of the range payload magnification obtainable with a short run, this ability will provide the force commander with a wide number of options about how best to balance VTOL and CTOL constraints since, whether or not it employs a catapult, once the aircraft requires a deck run it develops sensitivities to wind direction.

Recent results with the Harrier--ski jump combinations indicates that for many applications STOVL is an attractive mode of operation. It was considered infeasible for use on the large carriers because of the space consumed by the ski jump if fixed, or the complications involved if it is made retractable. Under such circumstances use of the existing catapults with normal CTOL's made more sense.

During the initial discussions of the operations of V/STOL aircraft from large carriers, no attempt was made to restrict consideration to any particular mission category. Rather it was assumed that the machines could be fighter/strike aircraft in which case they might well be supersonic, or they might equally well be airborne early warning (AEW) or ASW aircraft in which case they could well be subsonic. The possibilities of a subsonic missileer combat aircraft were also considered as was the advanced technology involved in the development of a ship launched, air targeted missile (SLAT).

When one considered the maturity of technologies available, with the exception of the AV-8B which could perform some naval subsonic combat roles with only slight modification, it appeared that it would be at least eight to ten years before any of the V/STOL concepts considered could provide an operational capability. In this regard the high-speed high-altitude support aircraft can be brought to operational status in the earliest time frame. (The Tilt Rotor or the ABC could also be developed in this time frame if their use in the AEW or ASW roles is found to be attractive.)

Although it appeared that V/STOL, if available, would provide the large deck carriers with important tactical flexibility, it did not appear to the Task Force to significantly alter the basis for the increasing concern regarding the combat survivability of our limited carrier force, a concern which has placed in jeopardy the program for the orderly replacement of these ships as they reach retirement age, thus posing for the Navy a severe problem in the maintenance of future force levels.

The two options that appear available are either to build more large carriers, in which case force levels will probably continue to decline due to the large single unit procurement costs, or to procure for the same investment a larger number of smaller sized carriers which provide better force survivability both through dispersal and the lessened impact of the loss of a single ship. The first option is unattractive because of vulnerability concerns, while the second is unworkable without combat aircraft that can operate from the smaller carriers being considered with the performance required to meet the projected threat.

With the carrier programmed in FY 80 budget the Navy can maintain the current force of 12 deployable large deck carriers to the year 2000 by means of the service life extension program (SLEP). Beyond that the force level will decline to zero by about 2015 unless replacements are constructed. It seems unlikely that this will be done in the numbers required to maintain the force levels, so alternate solutions are required. If these solutions are to include sea based air, and the Task Force could see no way for the Navy to perform its mission without it, the development of suitable V/STOL aircraft is critical.

About the minimum sized warship practical for the operational basing of high disc loading combat aircraft is of the order of 20,000 tons, a conclusion based both upon the space available for maintenance and logistic support of reasonable numbers of machines, and the necessary sea keeping characteristics to assure nearly all-weather operation. Under certain conditions it might prove possible to stage such aircraft through the large numbers of helicopter platforms available throughout the fleet providing a flexibility of operational concepts involving dispersal of forces. Primary basing of one or two aircraft upon these smaller ships does not, however, appear feasible.

Ironically, a V/STOL carrier (VSS) could be in the fleet as early as 1986 (FY 81 budget ship building programs) even though the aircraft designed to use it might lag by another four years. Fortunately such a ship would be a valuable fleet asset, even with only currently available aircraft, in the areas of amphibious assault (LPH replacement), amphibious fire support (AH-IT and AV-8A and/or B), mine warfare (53H-1M), and ASW (LAMPS). At the initial operating capability (IOC) of the V/STOL aircraft be it a supersonic fighter, an AV-8 derivative, or a missileer, the VSS would be able to carry out the general naval superiority mission in independent operations. With the introduction of high altitude, high speed support aircraft configured for ASW or AEW missions, along with the potential available through the development of new concepts such as SLAT and SOJM, such a vessel would be able to conduct independent military operations across the full spectrum of naval warfare.

- V/STOL aircraft development appears essential if sea based air is to continue to be a viable element of the U.S. Naval force.

- Although such aircraft can add greatly to the flexibility of large deck carrier operations and should be added to their air groups as they become available, their greatest impact will occur if developed jointly with platforms specifically designed for their operation.

- The ski jump concept used in conjunction with vectored thrust aircraft will provide an operational flexibility because of the range/payload tradeoff's available if one accepts constraints on ship operation similar to those of a large carrier (space, weight and/or complexity of the ski jump itself, the clear run space required and the necessity of heading into the wind to launch--although tests have shown the system to be surprisingly tolerant of cross winds). Verticle takeoff and landing capability in an off-loaded condition is a critical necessity.

- It did not appear to the Task Force that low-speed low-altitude support aircraft other than conventional helicopters held much promise for substantial operational imporovement. However, the existence of the Tilt Rotor (XV15) aircraft provides an important opportunity to evaluate such potential improvement at little cost.

- A high-speed high-altitude support aircraft configured for the AEW and ASW missions appeared to the Task Force to be highly desirable and, moreover, can be demonstrated in an early time frame at low cost. As new concepts such as SLAT are developed such machines may be configured for the targeting role. Some variations may be suitable for use as a missileer should that concept appear feasible.

- The AV-8B, or its "navalized" version of the AV-8B+, can perform a variety of subsonic naval missions, is a mature technology, and can provide valuable operational experience. Although without the addition of new funds, the machine cannot be procured in large numbers, it seems highly desirable that specific research and development funds be made available so that a number can be obtained in order to conduct operational research into the problem areas of the command and control of dispersed aircraft and to examine the feasibility of staging and small platform loitering maneuvers.

- A supersonic V/STOL fighter with a 15-year development time seems like a reasonable F/A 18 follow-on.

## Marine Corps

Because of the highly mobile nature of Marine Corps equipment designed for amphibious landings, the dispersed forward base concept employing AV-8's has been shown to be both logistically and operationally feasible. As the Corps continues to experiment with operational concepts, it is expected that such operations will become increasingly streamlined and responsive to the needs of the battlefield. Depending upon the situation, the vulnerability of aircraft in the ground loiter mode, both to direct enemy action and sabotage, may become serious concerns.

In their operational concept, close air support as embodied in the AV-8, is treated in much the same manner as organic artillery. It seems likely to the Task Force that the AV-8B will satisfy this requirement throughout the time period under consideration although concern was expressed that the design does not contain any provisions to reduce its vulnerability to battle damage.

Because these aircraft are treated as extensions of artillery, plans call for them moving ashore as rapidly after the initial assault as possible, thereby freeing the Navy vessels from the immediate vicinity of the land action. Until it becomes possible to establish airfields ashore, however, air superiority must still be maintained by naval aircraft flying from carrier decks. If a STOVL first line fighter is produced for either Navy or Air Force use, it will obviously be of great use to the Marine Corps and will greatly add to the flexibility of operations by permitting the entire air support of the operation to move ashore as rapidly as $C^3$, logistic and maintenance support will permit it, thereby freeing the Navy for other missions.

Like the Army, the Marine Corps make extensive use of light disc loading aircraft. The primary use is in the vertical assault mission. Although there has been recent interest in the possibility of holding the amphibious ships at distances of up to fifty miles off shore, since the vast majority of the logistic supply must come across the beach, it appears likely that considerably smaller distances will be used in practice, particularly since studies indicate that the reduction of ship vulnerability scarcely warrants the problems associated with greater stand-off distances. In general, the landing sites selected for the vertical assault will be within 50 miles of the beach--usually far closer to avoid the possibility of the two assault forces (the one across the beach and the airborne one) being kept isolated from each other.

The result is that, although at one stage the distances from ship to landing site seemed large enough to place considerable emphasis on speed both for increased productivity and decreased vulnerability, more recent studies tend to emphasize the same factors that concern the Army, i.e., low downwash velocities and high lifting capacity. It is likely, therefore, that Marine Corps interest will center on evolutionary development of the helicopter with only minor interest in such devices as Tilt Rotors or ABC. In general, the high downwash velocities of the V/STOL A candidates make them impractical for assault missions.

- The Marine Corps concept of organic close air support is built around the AV-8 aircraft. For some missions the combination of this aircraft with armed helicopters is most efficient, but for missions requiring penetration beyond the immediate forward edge of the battle area (FEBA) the speed of the AV-8 seems essential. Although not specifically designed to reduce battlefield vulnerability, the AV-8B appears likely to be the best aircraft available for the mission during the time period of concern.

- The existence of a first line V/STOL, STOL or STOVL fighter would greatly aid the flexibility of Marine operations and would probably be adopted if developed for Air Force or Navy application.

## Air Force

The Air Force has recognized an immediate air base vulnerability problem particularly in the NATO environment in which its bases are not only within range of Soviet air strikes, but in many cases are known to be targeted by

Russian missile forces. Current assessments indicate that in case of war various forms of runway denial weapons may be employed by the USSR including chemical warfare and antipersonnel weapons along with pavement breakers.

Because of its large inventory of CTOL aircraft, and because of the cost and time that are expected to be required for the development of V/STOL aircraft of roughly comparable capability, such machines are not viable solutions to the immediate problem although they may become so in the out years. A variety of approaches utilizing the existing fleet of aircraft were discussed. Included were:

a) A study of what is required to permit operation off unpaved runways including landing gear and wheel redesign if necessary.

b) The development of balanced field length operations, i.e., the reduction of the landing length to that needed for takeoff, possibly by use of retrofitted lift improvement systems, thrust reversers, and the possible use of arresting gear.

c) Evaluation of operation in the resulting STOL mode either from segments of the main base or from dispersed sites to the degree that the aircraft can be maintained and supported at such sites. The logistic support and routine maintenance supplied at dispersed sites received considerable attention from the Task Force. It was suggested that the Air Force examine the Marine Corps techniques associated with the support of amphibious landings as a possible model of an approach to the system to be employed. It was further suggested that the role of advanced STOL cargo aircraft and/or heavy lift helicopters be evaluated as a method of keeping such dispersed sites adequately supplied.

d) The development of adequate command, control and communications ($C^3$) systems to allow coordinated operations from dispersed sites. Soviet doctrine places great emphasis upon disabling enemy $C^3$ either by direct attack or electronic countermeasures, thus this element of dispersed operations may be even more critical and difficult to solve than the logistic problem.

e) The investigation of the possibility of the long term development of STOL or STOVL aircraft to replace the present fleet. It was pointed out in these discussions that in the event the Air Force requires vertical takeoff aircraft a VATOL machine may well represent a desirable solution for this aircraft, in that of all configurations so far investigated it makes the fewest sacrifices in weight and high speed performance to achieve VTOL capability. Properly designed, it may in fact out-perform a CTOL machine since it need not be burdened with conventional landing gear or high lift systems. There is a natural reluctance particularly on the part of pilots to consider such a solution but, given the performance of the X-13, it seems as much socialogical as technological. The potentials of the design should not be overlooked.

- The Air Force has an immediate air base vulnerability problem in NATO and elsewhere. Solutions must be sought that will permit the existing fleet of aircraft to counter the threat by

operating from heavily damaged sites. This will probably involve developing the capability to operate from unpaved runways and the use of balanced field lengths achieved partly by changes in the existing aircraft lifting and thrusting arrangements and partly by means of arresting systems.

- Off main base dispersed site operation appears essential. Methods of achieving this goal will possibly involve patterning logistic and maintenance support after the systems currently employed by the Marine Corps, and the development of a resilient and flexible $C^3$ system.

- Thought must be given to the basing flexibility that can be achieved by V and/or STOVL machines with first line fighter capability to be introduced by the latter part of the century, probably during the early 1990s. It is, however, not clear at this time that the increment in basing flexibility achievable with such a machine over that available through the use of improved high lift devices and arrestment systems will warrant the cost of development of such a machine.

Army

Of all the Services, the Army appears to have the least need for V/STOL aircraft other than the helicopter. Since it is constrained by battlefield conditions to fly in the nap of the earth, there is a limit to the advantage that can be gleaned from increased speed. Because the operation of its aircraft is frequently within the vicinity of troops and equipment, it has a requirement that downwash be kept as low as possible--an attribute which also reduces visibility, and hence vulnerability, over dusty or sandy terrain.

Because of the nature of the Army's assigned mission, it has no need for the use of subsonic nor supersonic combat aircraft. Although there may be a need in intelligence gathering, observation or electronic warfare missions for an aircraft more capable than the conventional helicopter, the Task Force could identify no particular mission enhancement resulting from the use of high-speed high-altitude support vehicles of the types generated by studies conducted in connection with the Navy's V/STOL A requirements.

As a consequence, attention was focused upon the possible use of low-speed low-altitude support aircraft typified by the Tilt Rotor and ABC concepts currently under development. It was concluded that should such aircraft be available, they would be well adapted to perform these special missions, but the numbers required would be small and would scarcely justify the rather substantial development required should these machines not be required in large numbers by the other Services. Indeed, it appeared that low disc loading craft adequately met the present and projected needs. It is expected that improvements to such craft will be evolutionary and will be introduced into the force as they become available.

Because of this the Task Force found it curious that the Army was providing major support to both the Tilt Rotor and the ABC, both vehicle concepts of limited usefulness within the defined mission area. Seemingly of greater concern than the development of faster V/STOL aircraft should be increased rotor efficiency and reductions in cost and complexity.

No briefings were presented to the Task Force on the need for heavy lift helicopter either as an aid to battlefield mobility or in a logistic support role--particularly the unloading of ships when port facilities have been damaged--but a number of the members expressed concern about the adequacy of the current technology programs in support of this concept. Given the data available, it was felt no express recommendations could be formulated but that this concern should be recorded.

- Only marginal improvement in Army mission capabilities can be expected from the introduction of advanced V/STOL technologies.

- A clearer rationale for Army interest in the ABC and Tilt Rotor concepts is needed, recognizing that these programs address primarily the technology for rotorcraft having speeds in excess of 300 mph.

- The Army should review the adequacy of its heavy lift helicopter technology programs in light of the potential need for heavy vertical lift capability required in the European theater and elsewhere.

## PART II

## Technology

The second part of this report is a review of the current status of V/STOL technology in relation to its readiness to support a possible decision to produce V/STOL aircraft in support of important military mission requirements just outlined. The section will also identify specific technology development and demonstration programs which must be pursued to provide adequate confidence in such decisions. Some consideration of priorities is undertaken as this Task Force understands the serious fiscal constraints now in force.

### Configuration Technology

Potential V/STOL aircraft can be considered in several categories, as follows:

(1) Low-speed low-altitude support aircraft (subsonic)
(2) High-speed high-altitude support aircraft (subsonic)
(3) Combat aircraft (subsonic)
(4) Combat aircraft (supersonic)

These categories are sufficiently distinctive in their characteristics that it is unlikely that any two can be combined into a single multi-mission aircraft, with the possible exception of the two subsonic aircraft the functions of which can possibly be combined into a multi-mission aircraft.

### Low speed, low altitude, support aircraft

The low-speed low-altitude VTOL aircraft requirements can be satisfied most readily by the development of rotorcraft having higher speed and cruise efficiency than the conventional helicopter. The technology for such aircraft has been developed over a period of many years to the point that two concepts, the Tilt Rotor aircraft and the Advancing Blade Concept helicopter, are both in the flight demonstration phase (i.e., the XV-15 and the X59A, respectively) and are expected to achieve maximum speeds in excess of 300 mph. These flight demonstrations, at approximately half-scale, are sufficiently representative to permit accurate assessments of a mission-scale vehicle. Further improvements in the Tilt Rotor can be anticipated at relatively modest technology investments through fly-by-wire active control technology and the introduction of composite rotors. The ABC concept requires the development of a suitable integrated propulsion system which powers the counter-rotating rotors and additionally provides forward thrust during cruise flight. Both of these rotorcraft have the potential for low spotting factor if additional mechanical complexity is accepted. The technology for a low speed low altitude support aircraft can be brought to a high degree of confidence by 1983.

- The technology for a low-speed, low-altitude (e.g., 300 knots, 25,000 feet) V/STOL support aircraft has matured to the point that it will permit a full-scale operational vehicle development decision in 1983. Technically, the Tilt Rotor Concept is the primary candidate in this category in view of the availability of suitable engines and a well-established base of technology including the ongoing (XV-15) flight demonstration program. The ABC is considered a backup concept although it is limited in its cruise performance potential and requires the development of an integrated propulsion system.

High speed, high altitude support aircraft

The high-speed, high-altitude support aircraft is also technically within reach primarily as a result of available engine technology derived either from the Pegasus engine (used in the Harrier) or the higher bypass engines used in commercial transport aircraft. This propulsion technology, with appropriate additional developments, can provide aircraft capable of speeds up to 450 knots and altitudes of 45,000 feet. Because of the greater thrust to weight fraction of the engine in any VTOL aircraft, the question of the design philosophy for engine-out landing capability becomes significant. For support aircraft, which carry multiple crew, passengers, and costly equipment, the ability to return to a landing site is mandatory and these aircraft therefore require multiple engines. A two-engine configuration meets this criterion but requires large engines (i.e., each having thrust equal to aircraft weight) if a vertical one-engine-out capability is required. A more reasonable approach is to provide higher engine reliability through incorporation into the design of improved emergency power rating, adequate stall/surge margins, combustor stability margins and backup manual fuel controls. The requirement for one-engine-out verticle landing should be eliminated; if a stabilized deck of 500 foot length is provided, a two-engine VTOL aircraft can complete a STOL landing in the advent it returns from a mission with one-engine inoperative.

The most straightforward approach to a two-engine high-speed, high-altitude support aircraft may be through the use of Pegasus engines. These engines have been well qualified in VTOL operation and have proven extremely dependable during verticle takeoff and landing operation (on no occasion has loss of thrust been experienced with the Harrier AV-8 in the vertical mode, although engine-out situations have occurred in horizontal flight due to bird ingestion). In the two-engine application appropriate to the support aircraft the engines can be cross-ducted to provide one-engine-out STOL landing capability very easily. The modest by-pass ratio of 1.4 provides good cruise performance with good excess power for evasive manuevering. An aircraft utilizing this approach would also have a significant advantage in using the same powerplant as the Marines Harrier AV-8A. It is the least dependent on new technology and could be demonstrated in flight by 1983 at very modest cost.

A second approach to this category of VTOL aircraft would use two lift/cruise fan engines of high by-pass ratio, cross-coupled mechanically to provide one-engine-out STOL landing capability. The engine technology is well-developed but the development of mechanical cross-coupling of the engines (i.e., gear/shafting across the fuselage) is required. A number of preliminary designs for VTOL aircraft using this approach have evolved over the past years (also more elaborate 3 and 4 far configurations) and extensive wind tunnel work has been accomplished on some versions. This approach requires flight demonstration and the necessity for development of mechanical cross-coupling. With a focused effort, this approach could be demonstrated in flight as a subscale aircraft by the mid 1980s.

A third possible approach to this vehicle would use the X-wing rotorcraft, which operates as a helicopter at low speed and as a fixed-wing airplane with two swept-back and two swept-forward wings in horizontal flight. The technology development for this configuration is in its early phases with the recent completion of the first wind tunnel tests for a small scale version of the vehicle. Substantial further study and ground-based investigation at a larger, more representative, scale are required before the practicality of this approach can

be assessed. The primary technology development required for this type of vehicle is an integrated propulsion system that provides forward thrust, power to drive the rotor and secondary air to the rotor for circulation control blowing through the leading and trailing edges of the blades. (This propulsion development is similar to that required for the ABC, but with the additional complexity of the pneumatic control system for the rotors.) The demonstration of this technology in-flight, at a representative scale, could be accomplished by the late 1980s.

o The technology for a high-speed, high-altitude (e.g., 450 knots, 45,000 feet) V/STOL support aircraft requires further development and flight demonstration before a decision can be made to proceed with an operational vehicle development. This aircraft would be a two-engine configuration permitting VTOL operation under normal conditions and permitting recovery to ships having a 500 foot deck in the event of a one-engine failure during the mission. There are at least three approaches to this kind of aircraft:

(a) The first approach, in terms of technology readiness would use two Pegasus (Harrier) engines in conjunction with an airframe derived from the S3 ASW aircraft. Such an aircraft could be demonstrated in flight by 1983.

(b) The second approach is a lift/cruise fan aircraft for which substantial technology is available to provide suitable high by-pass ratio engines. Flight demonstration of this concept can be accomplished by 1985, with engine cross coupling, if an engine modification program is initiated in 1980.

(c) The X-wing is also a possible candidate; however, it requires substantially more ground-based component technology development and ultimately the development of an efficient integrated propulsion system that provides forward thrust, primary power to the stoppable rotor in hover, and secondary air supply to the rotor pneumatic control system.

Subsonic Combat Aircraft

The technology for one subsonic VTOL combat aircraft (the Harrier AV-8A) has evolved over a period of twenty-five years and provides a good basis for this category. Improvements to this configuration continue to be made with the incorporation of lift-improvement devices and the introduction of composites into the wing structure. Further increases in radius (up to probably several hundred miles) are possibly by incorporating advances in engine components in conjunction with new operational techniques such as the "ski-jump" launch ramp. This relatively simple approach to a VTOL combat aircraft lends itself readily to the phased introduction of technology improvements, particulary in propulsion and structure, and should be considered the prime candidate for an advanced subsonic VTOL combat aircraft.

By comparison, other VTOL combat aircraft concepts are in a relatively early stage of technology development. The Thrust Augmented Wing (TAW) concept is not well adapted to use as a subsonic combat aircraft because of its inability to carry wing-mounted stores; moreover,the configuration is mechanically complex and the low speed performance of the wing and canard are sensitive to the internal geometry of the augmentor system and possibly to attitude control requirements and forward speed effects. Efforts to bring this configuration to flight status have failed because of the poor augmentor performance and, even when this is

corrected through redesign, there remains a great deal of uncertainty as to whether this will result in a flyable airplane. This concept needs a more comprehensive technology base before it can be considered as a viable contender for development.

o The Harrier has demonstrated important capabilities in the subsonic combat aircraft category despite the fact that much of the technology incorporated in this aircraft is now more than 20 years old. Technology developments in propulsion (e.g., improving the engine/thrust weight by 50%) structures and control systems that have evolved since 1955 permit the design of an aircraft of this type with substantially better performance in terms of payload fraction and/or range. The TAW concept could be considered a back-up for this category of aircraft; however, the TAW is inherently limited in its ability to carry external weapons, is mechanically complex, and its performance is critically sensitive to changes in the wing-canard geometry and possibly to attitude control requirements and forward speed effects at low speed. Substantial technology advancement is required in order to gain confidence in this approach to VTOL.

Supersonic Combat Aircraft

In this category it is important to distinguish between STOL and VTOL aircraft. The technology has been brought to the point where it is possible to develop a supersonic STOL combat aircraft (of interest to the Air Force) which has comparable performance to the best CTOL combat aircraft available today, say F16/F18; here STOL is defined as an aircraft capable of takeoff and landing from 1500 foot to 2000 foot runways. The primary need is for the incorporation of high lift devices, possibly including the use of the aerodynamic blowing; to improve the short field landing capability of supersonic combat aircraft.

The technology for both horizontal attitude takeoff and landing (HATOL) and VATOL supersonic combat aircraft requires several years of more intensive development before sufficient confidence is established to define an operational aircraft. An intermediate capability, STOVL at an intermediate Mach number ($M = 1.6$), may be technically feasible through the use of plenum chamber burning in the Pegasus engine. While the ultimate potential for this approach is limited, it may be considered as an interim capability available for the 1990s, based on modest extensions of existing technology. The vertical attitude takeoff and landing (VATOL) approach does not require significant vectoring of the thrust with respect to the airframe. In this configuration however, significant operational problems associated with landing on the side or rear of a moving ship remain to be resolved and would require complex landing devices on the ship.

o In the supersonic combat aircraft category the technology is currently inadequate to support any configuration having vertical takeoff or vertical landing capability. It is anticipated that technology would permit the development of a supersonic STOL combat aircraft, capable of operation from 1500 feet to 2000 feet runways for the 1990s, through the blending of aerodynamics, proplusion and control technology into an advanced configuration, i.e., a STOL vehicle comparable in performance to the F-18; a supersonic ($M \sim 1.6$) STOVL variant of the Harrier propulsive approach may also be technically feasible (through the use of plenum chamber burning) during the 1990s. Major technology improvements in lift engines and control systems, coupled with very careful airframe/propulsion/control system integration, will be necessary in order to evolve a true supersonic VTOL-capable combat aircraft by the year 2000. In this regard, both horizontal altitude (HATOL) and vertical altitude (VATOL) configurations deserve further study.

## Ship Considerations

The degree to which any of the foregoing aircraft can be expected to operate successfully from ships at sea will depend in part on the design of the ship and the sea state. While the versatility of VTOL aircraft is enhanced if they are designed to operate from small ships under a variety of weather conditions there is a practical limit, in terms of the resulting complexity of design and operation, that should be imposed on the aircraft. In this regard the aircraft design, and the operating tasks required of the pilot, may be substantially simplified if the ship is given some degree of stabilization, and if it is equipped with devices that assist the aircraft in takeoff and landing.

Provision of a through deck with a length of 500 feet, with a simplified arresting gear, substantially eases the one-engine-out emergency landing problem for a VTOL aircraft (as noted earlier) and reduces the aircraft design thrust/weight ratio from approximately 2.2 to 1.1 with a very significant impact on aircraft range and payload. A partially roll-stabilized ship can permit operation in sea-states in excess of 6 compared to sea-states of 2 or 3 nonstabilized ship. The possible use of small waterplane area twin hull (SWATH) technology to obtain a stable platform needs to be assessed.

Perhaps, the greatest benefit from technology can result from the incorporation aboard ship of advanced sensing systems that communicate to the aircraft (i.e., to the pilot or the control system) the necessary information relating to the position and velocity of the landing site to reduce the uncertainty and pilot workload associated with VTOL landing in adverse visibility conditions. A number of alternative systems should be explored ranging from simple information assistance to the pilot to fully automatic electronic coupling between the ship and the aircraft control system.

o In the design of ship platforms it should be recognized that provision of a through deck of approximately 300 to 500 feet in length (particularly if equipped with a "ski-jump" launch ramp) can substantially improve the performance of those VTOL aircraft that have a STOL overload capability; furthermore, a deck length of 500 feet would permit subsonic support aircraft to land in a STOL mode in a one-engine-out emergency condition. Advanced technology deck-mounted landing aids may help reduce the high pilot workload of VTOL aircraft in adverse weather conditions.

## Propulsion Technology

The performance and characteristics of the propulsion system are of varying importance for the different VTOL aircraft concepts. In low speed rotorcraft such as the helicopter and Tilt Rotor aircraft, the engines are not controlling, though the drive system is. For higher speed concepts such as the X-wing the propulsion system becomes more critical since it must deliver high maximum powers for the high speed thrusting mode, as well as driving the rotor and providing air for blade lift control at lower speeds. For medium speed aircraft using high by-pass lift-cruise fans the propulsion system weight and configurational requirements tend to dominate the aircraft design, and this is equally true for high subsonic vectored lift attack aircraft. It is not yet clear for aircraft requiring supersonic capability how much compromise with the supersonic requirement can be allowed in order to achieve vertical landing (and possibly takeoff) capability. In the configurations using dedicated lift engines for VTOL the

aerodynamic compromise is minimal, while the weight and complexity of the added lift engines have a serious impact on aircraft payload and range. In the proposed extension of the AV-8 concept to supersonic capability by plenum chamber burning, the aerodynamic performance at supersonic conditions is seriously affected, while the change in the engine is modest.

For these VTOL aircraft which are propulsion critical, the ground rules laid down for the propulsion system have a controlling influence on system capability. In multi-engine configurations the requirement for one-engine-out vertical landing capability in particular has major consequences, as it effectively imposes a thrust/weight in excess of two for two-engine configurations and thereby substantially reduces the mission effectiveness of the aircraft. The reliability of modern gas turbine engines is such that it seems reasonable to consider deleting this requirement in favor of increased emphasis on engine reliability. The record of the Harrier, with no aircraft losses due to engine mechanical failure, shows that this is a viable approach to propulsion system reliability. Furthermore, in multi-engine configurations a one-engine-out short landing capability can be retained.

Technology advances which will have large benefits for these propulsion critical VTOL concepts are identifiable across the whole range of materials through fluid mechanics to control, but it seems useful to divide them into three categories: first those which improve the thrust to weight ratio and fuel consumption of the engine, second those which improve reliability and finally airframe/engine controls which reduce the demands on the propulsion system.

The needs in the first category are well recognized. Higher tip speeds and stage loadings in compressors reduce compression system weight and volume. Higher turbine inlet temperatures, particulary for the short times required for takeoff and landing similarly reduce engine weight and enable better matching between maximum thrust and cruise requirements. Composite materials offer lighter fans and cases, and potentially better aerodynamic performance through elimination of part span shrouds in fans, for example. Variable turbine nozzles permit better matching of the engine to both vertical thrust and cruise requirements. While all these technologies are under development at present, the efforts are not focused at a VTOL requirement.

In the second category are the technology developments required to raise the operational reliability of engines to a level such that engine-out capability will not be required. They include better understanding of stall and surge and combustor blowout limits, which will permit design to avoid engine failures due to these phenomena. Technology is emerging which will permit the design of engine control systems with the capability for detecting degradation of engine components which may lead to failure. This could have a very large payoff in the VTOL engine.

Finally, in the third category are the integrated engine/airframe control systems which are required to enable automation of the landing maneuver and hence reduce the hover fuel requirements. Experience from the Harrier indicates that even with manual landings the maneuver can be preprogrammed, so that landing fuel reserves need not be large. With automation they should be reducible even further, and the optimization of the propulsion system weighted more toward the cruise, combat and loiter requirements.

Since the control system in this case becomes flight safety critical, it must have reliability comparable to that of the airframe structure, and this will require networked fault tolerant digital systems. With such a control system in place, the entire vehicle can be control configured with resulting performance benefits throughout the system. For example, lower control authority will be required, hence less installed thrust for the landing maneuver.

These technologies are all nascent. What is required to bring the needs and opportunities together are some realistic requirements for jet-lift aircraft. Three types of propulsion systems can be distinguished. A vectored-lift system using the best available technology, and aimed at a high subsonic attack aircraft such as the Harrier is one. The second is a lift-cruise fan for the AEW and ASW missions. The third is a lift engine and thrust engine combination for an air superiority fighter with STOVL capability.

## Avionics Technology

The ability of an aircraft to takeoff and land vertically appears to have comparatively little impact on its flight and mission avionics; the exceptions appear to be those of aircraft control during vertical takeoff and landing and the indirect consequences of a restricted payload.

### 1. Flight Avionics

With respect to flight avionics, the technology needed to design and produce a fully automated landing system of very high reliability is in hand. It is not, however, fully established that such is needed nor that the resulting system would be affordable.

The British see no requirement for automated landing. They state that the Harrier is easily controlled by the pilot, and their operating experiences appears to corroborate this claim. On the other hand, proponents of automated landing point out that ease of control is not the whole issue since an automated control system might save as much as two minutes of hover time per mission. They equate this savings in time to a reduction of 5,000 pounds or more in the gross takeoff weight of 40,000 pound VTOL aircraft. This estimate is probably generous to their cause, but they have a point.

Out technologists have developed workable concepts for ultra-reliability and have begun work on proof of concept demonstrations, but the architecture of operational systems is not fully defined. Key elements of an ultra-reliable system include redundance at the macrocomponent level, a limited capability for self-organization (in the sense of time division communications networks such as "packet"), and a substantial self-diagnosis ability. Such systems have been referred to a fault-tolerent, and the expectation is that even though components and macrocomponents of the system will inevitably fail, functional failures will be at least as rare as (say) structural failures in the basic airframe.

The dispersal of forces, a major consideration supporting the military use of V/STOL aircraft, also requires a high reliability in all avionic systems. We have not thought out all of the possible implications, but two observations impress us deeply. These are (1) that 20% or more of a small ship's firepower may be vested in a single hanger queen, and (2) repair and maintenance on small ships will necessarily be austere. It seems better to avoid failures than to make repairs.

The sense of the panel is to favor the development of an automated landing system. In part, this view derives from a recognition of the need for fault-tolerant systems in a variety of military and civilian applications; although the present need for automation is not yet established, a V/STOL flight control is an excellent example of that class of system which, if automated, must be extremely reliable. A second factor warranting consideration is that although the Harrier appears to be relatively easy to fly, some V/STOLs of the future are likely to prove hard to handle. A start in the development of an automated control at this time will hedge this future need. For these reasons, the development and extensive testing of a fault-tolerant flight control system for an existing helicopter is recommended to demonstrate that very reliable avionics systems can be designed and produced at reasonable cost.

Both the dispersal of forces and the smaller payload of the V/STOL dictate reconsideration of the $C^3$ problem. Forward-based V/STOL strike aircraft in the so-called ground loiter mode stress the communication capabilities of land forces, but the solution to this will probably evolve out of the artillery fire control network since the needs are similar. The operation of aircraft in a coordinated manner from a number of small ships will create a command problem, but future tactical data systems will be able to cope with this requirement. The one area which worries us in particular is the possible separation of operators, controllers, and task commanders from their sensors and weapons as may be required to perform the ASW and AEW missions. As noted before, we do not specify here the size of the V/STOL so it is not possible to conclude that such separation will be necessary. Also, data linking of V/STOL sensor information to a central command position will be feasible.

The solution to the task of providing adequate AEW involves selecting between miniaturized $360^{o}$ conformal arrays and in the C- or X-band for radar operation. The cost of using side-looking arrays will be to lose coverage in $60^{o}$ sectors fore and aft of the aircraft and experience a modest number of weather induced outages. The gains (relative to our present AEW) will be greatly improved resistance to jamming, better target location, and significantly greater initial detection range.

## Conclusions on V/STOL Subsystem Technology

The following conclusions are drawn with respect to aircraft subsystem technology:

- A systematic exploration of the alternatives for simplifying VTOL aircraft piloting tasks is needed, ranging from fully manual control to use of fully automated, highly reliable, distributed control systems (such as developed for the shuttle spacecraft) in order to determine the impact of such alternatives on the safety of operation and the cost of development and operation of VTOL aircraft.

- The cost of an engine-out landing capability is so high for jet-lift VTOL that it should be abandoned as a requirement. In its place, emphasis should be placed on engine reliability, obtained through design features such as adequate stall/surge margins, combustor stability margins, and possibly backup manual fuel controls such as used by the Harrier AV-8A. No Harrier has so far been lost due to engine failure in takeoff or landing.

- The AV-8A is a viable aircraft in the Northern European battle scenario in the judgment of the RAF, and this with an engine originally designed in 1957, with a present thrust/weight ratio of about 5.7. Using current technology it is possible to build and develop an engine with about the same (1/1) bypass ratio with a thrust to weight ratio of 10 and to current standards of curability and reliability. It will also have significantly lower specific fuel consumption. Such a propulsion system would yield an aircraft with a great deal more capability than the AV-8B, which appears to be competitive with the A-18 for the close air support mission.

- Integrated automatic control of the engine and airframe during approach and landing offers large savings in fuel consumption. To realize these advantages the control system must meet standards of reliability, fault tolerance and damage tolerance comparable to those imposed on the aircraft engine and structure. Fault tolerant, dispersed digital systems have the potential to meet these requirements.

- A number of concepts providing supersonic capability with horizontal attitude VTOL require dedicated lift engines for takeoff and landings; a firm requirement for such a capability may emerge in the near future, but there is no engine program in existence to provide a state-of-the art lift engine.

- The difficulty of integrating nonjammable conformal radar, having 360$^{\circ}$ coverage, into the aircraft wing suggests that alternative approaches (such as fuselage mounting of partial azimuth coverage radar) should be considered for use on AEW aircraft.

APPENDIX A

TERMS OF REFERENCE

28 April 1978
15 March 1979

APPENDIX A

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

28 APR 1978

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Task Force on V/STOL Aircraft

Please establish a Task Force to evaluate the potential of V/STOL technology for future replacement of our present, conventional (CTOL), land-based and sea-based, supersonic tactical fighter aircraft.

I would like to have the DSB:

1. Review past and present V/STOL concepts.

- Problem areas
- Identify key technology issues
- Aircraft performance potential
- Mission performance potential
- Operational requirements

2. Review status of technology for V/STOL including advanced helicopters.

- Structures
- Aerodynamics
- Engines
- Flight control systems
- Avionics/Radar

3. Assess risks and recommend appropriate technology demonstrations needed for a supersonic, V/STOL, fighter aircraft development program.

- Technology development
- Test bed demonstrations
- Prototype demonstrations
- Full scale development
- Go/no go decision points
- Management approach

The Task Force should plan to have a final report by 1 October 1978. It would be most helpful to have an interim report in July 1978. I have appointed Mr. Ken Hinman of the Office of Air Warfare as the Executive Secretary for this Task Force.

Gerald P. Dinneen

Gerald P. Dinneen
Principal Deputy

APPENDIX A

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

15 MAR 1979

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Task Force on V/STOL, Phase II

You are requested to organize a Defense Science Board Task Force to review applicable technology and determine the general characteristics of a V/STOL aircraft which current and near term technology will support, and recommend meaningful naval and military missions that such an aircraft could conduct.

The Task Force should address the following:

A. Background

Phase I of the Defense Science Board Task Force on V/STOL Aircraft was conducted in 1978. The final report of that Task Force will be published, noting the continuing Phase II effort. Among the findings of the Phase I Study were three which lead to the need for Phase II, as follows:

1. "This Task Force was not constituted to judge the Navy's rationale for V/STOL aircraft or to judge how important this capability is to the Navy."

2. "Today's state of the art in aeronautical technology does not permit a reasonable solution to the Navy requirements as stated in V/STOL A or V/STOL B."

3. "This airplane (AV-8B) lies within today's state of the art and with even further capability improvement could be an extremely flexible weapon system for real military requirements."

V/STOL aircraft based on current and feasible future technology are flexible systems having the potential to fill real military requirements, but cannot currently meet the requirements of a high performance CTOL aircraft. The wrong question has been asked, i.e., what type of V/STOL can replace high performance CTOL and when can it occur? The preferred question is, what are the real naval/military uses of V/STOL based on current and feasible future technology, and what is the proper mix of V/STOL and CTOL systems to take advantage of the capabilities of each in the environment of the 1980s and 1990s.

B. Specific Objectives

1. Review past V/STOL programs and evaluate why they have failed to produce a meaningful military capability.

2. Review and evaluate current and near term (1980s) V/STOL technology and determine the characteristics of a realistic aircraft that could have a meaningful military capability in the 1985-2000 time frame. The AV-8B type aircraft should be considered.

3. Review Service missions, particularly those Service communities not traditionally associated with CTOL aircraft, and determine how V/STOL type aircraft could enhance their capability.

4. Survey the field of emerging technologies, consider the strengths and weaknesses of systems that may result from these technologies, and determine which can contribute or benefit from V/STOL system capabilities. For example, would tactical cruise missiles benefit from having a V/STOL targeting aircraft associated with the launching unit?

5. Recommend the types of missions best performed by CTOL aircraft and a feasible, near term V/STOL aircraft, and determine what an optimum, evolving mix of these types should be in the 1985-2000 time frame. (Including rotary wint V/STOL.)

The Task Force will be sponsored by Mr. Robert A. Moore, Deputy Under Secretary of Defense for Research and Engineering (Tactical Warfare Programs). Dr. Courtland D. Perkins will continue as the Chairman of the Task Force. Commander Robert C. Powers, USN, Military Assistant to the Defense Science Board, will act as Executive Secretary.

The Task Force should plan to commence its efforts in April 1979, and submit a final report within six months.

William J. Perry

APPENDIX B

MEMBERSHIP
&
AGENDAS

# APPENDIX B

## MEMBERSHIP

## DSB TASK FORCE ON V/STOL AIRCRAFT, PHASE II

### Chairman

Dr. Courtland D. Perkins
President
National Academy of Engineering

### Members

Gen. Russell E. Dougherty, USAF (Ret.)
Consultant

Dr. Norman Grossman
President
Fairchild Republic Company

Professor David C. Hazen
Dept of Aerospace & Mechanical Sciences
Princeton University

Adm. James L. Holloway, USN (Ret.)
Consultant

Mr. Richard E. Kuhn
Consultant

Professor Jack L. Kerrebrock
Director
Gas Turbine and Plasma Dymamics Laboratory
Massachusetts Institute of Technology

Honorable Walter B. LaBerge
Under Secretary of the Army

Professor James W. Mar
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology

Mr. Charles E. Myers
President
Aerospace, Inc.

Dr. Leonard Roberts
Director
Aeronautics and Flight Systems
NASA Ames Research Center

Dr. George S. Sebestyen
President
Defense Systems, Inc.

Mr. E. C. Simpson
Chief, Turbine Engine Division
Air Force Aeropropulsion Laboratory

Dr. Leland D. Strom
President
Delphi Corporation

Mr. J. J. Welch, Jr.
Senior Vice President, Marketing
Vought Corporation

### Executive Secretary

Commander Robert C. Powers, USN
Military Assistant, DSB

# AGENDA

## Defense Science Board

## Task Force on V/STOL, Phase II

### First Meeting 10 April 1979

| Time | Event | Speaker |
|---|---|---|
| 0900 | Assemble in The Lecture Room, National Academy of Science | |
| 0915 | Chairman's Introductory Remarks | Dr. Perkins |
| 0930 | Review of Phase I | Dr. Perkins |
| 1000 | Review of the Terms of Reference, Phase II | Dr. Perkins |
| 1100 | Status of AV-8B Program | Mr. Hinman |
| 1200 | LUNCH | |
| 1300 | Navy/USMC Interest in V/STOL and Potential Naval Missions | Mr. Woolsey |
| 1400 | Army Interest in V/STOL and Potential Army Missions | Dr. LaBerge |
| 1500 | Air Force Interest in V/STOL and Potential Air Force Missions | Dr. Mark/Dr. Martin (Tentative) |
| 1600 | Adjourn | |

## AGENDA

DEFENSE SCIENCE BOARD

Task Force on V/STOL Aircraft, Phase II

Meeting on 25 May 1979

| Time | Topic |
|---|---|
| 1000 - 1100 | Navy Seabased Air Study Master Plan |
| 1100 - 1200 | Navy Smart Weapon Characteristics and OTH Targeting Needs |
| 1200 - 1230 | Air Force Scientific Advisory Board Report on USAFE Views of V/STOL Missions in Europe |
| 1230 - 1330 | LUNCH |
| 1330 - 1545 | Roundtable Discussion with Service Chiefs (or their representatives) Regarding V/STOL Role and Missions |
| 1545 - 1600 | Chairman's Time |
| 1600 | Adjourn |

Defense Science Board
Task Force on V/STOL, Phase II

AGENDA
for the Summer Study Meeting
25-29 June 1979
Woods Hole, Massachusetts

NOTES: (1) Briefers (with no more than 3 back-up personnel) are invited to the conference room only for the duration of their briefing or as requested by the Chairman.

(2) Because of the large number of briefings, close adherence to the schedule is suggested.

(3) Briefers are requested to stand by at least a half hour in advance of schedule time to allow for possible schedule fluctuations.

Monday, 25 June 1979

Subject Area Number One: Review of the State of National and DoD V/STOL Technology

Participants: DIA, NASA, Army, Navy/Marine Corps, Air Force

| Time | Briefing |
|---|---|
| 0830 - 0900 | Assemble and Greetings |
| 0900 - 1000 | DIA: Soviet V/STOL Technology, Roles and Missions |
| 1000 - 1200 | NASA: U.S. V/STOL Technology, Mr. Deckert |
| 1200 - 1300 | LUNCH |
| 1300 - 1400 | NASA: U.S. V/STOL Propulsion Technology, Mr. Stewart |
| 1400 - 1440 | U.S. Navy: Navy Programs for V/STOL Technology |
| 1440 - 1520 | U.S. Marine Corps: Marine Corps Programs for V/STOL Technology |
| 1520 - 1600 | U.S. Air Force: Air Force Programs for V/STOL Technology, Dr. Richey |
| 1600 - 1640 | U.S. Army: Army Programs for V/STOL Technology |
| 1640 - 1700 | Chairman's Time |
| 1700 | ADJOURN |

Tuesday, 26 June 1979

Subject Area Number Two: Review of existing V/STOL aircraft, V/STOL aircraft proposals, and proposals to integrate aircraft, sensor and weapon technology into functional V/STOL aircraft and appropriate launch platforms.

Participants: Industry

| Time | Briefing |
| --- | --- |
| 0800 - 0840 | McDonnel-Douglas: AV-8B, Mr. Gilbert |
| 0840 - 0920 | British Aircraft: AV-8B Technology, Mr. Hooper |
| 0920 - 1000 | Grumman: Fleet Air Enhancement via Subsonic Turbofan VTOL Aircraft Systems, Mr. Kress |
| 1000 - 1010 | BREAK |
| 1010 - 1050 | Boeing: Summary of Boeing V/STOL Technology, Mr. Caldwell |
| 1050 - 1130 | Vought: Summary of V/STOL Aircraft Design Studies, Mr. Patton |
| 1130 - 1210 | Northrop: V/STOL Technology, Mr. Patierno |
| 1210 - 1300 | LUNCH |
| 1300 - 1340 | General Dynamics: V/STOL Technology Requirements and Operational Applications, Mr. Petrushka |
| 1340 - 1420 | Bell: Update on Status of Tilt-rotor Technology, Mr. Spivy |
| 1420 - 1430 | BREAK |
| 1430 - 1510 | Sikorsky: ABC Program Update: Development Status and Mission Applications, Mr. Paul |
| 1510 - 1550 | DeHaviland: V/STOL Technology, Mr. Hiscocks |
| 1550 - 1630 | Rockwell: Progress Report on XFV-12A Development, Mr. Hancock |
| 1630 - 1700 | Chairman's Time |
| 1700 | ADJOURN |

Wednesday, 27 June 1979

Continue Subject Area Number Two

| Time | Briefing |
|---|---|
| 0800 - 0840 | DARPA/Lockheed: X-Wing, Col. Krone |
| 0840 - 0920 | British DoD: R&D Effort on Av-8B Type Aircraft |

Subject Area Number Three: Review of existing and potential mission needs and requirements that could be fulfilled by V/STOL-type aircraft and launch platforms

Participants: Offices of the Government and Armed Services

| Time | Briefing |
|---|---|
| 0920 - 1000 | OMB: V/STOL Affordability Issues, Mr. Carter |
| 1000 - 1010 | BREAK |
| 1010 - 1050 | OSD: V/STOL Policy Issues, Mr. Hinman |
| 1050 - 1130 | NRL/Grumman: V/STOL Defense Effectiveness Analysis, Mr. Schoenfeld |
| 1130 - 1210 | Bell Special Presentation: Adaptation of Tilt Rotor to V/STOL Missions, Mr. Spivy |
| 1210 - 1300 | LUNCH |
| 1300 - 1340 | Rockwell Special Presentation: Potential Impact of TAW-V/STOL on Air Warfare and Its Logistic Support, Dr. Bellar |
| 1340 - 1420 | IDA: Cost Effectiveness Evaluation of Alternative Carrier Task Forces, Dr. Bracken |
| 1420 - 1430 | BREAK |
| 1430 - 1510 | U.S. Navy: Navy V/STOL Roles and Missions |
| 1510 - 1550 | U.S. Marine Corps: Marine Corps V/STOL Roles and Missions, BGen. Cook |
| 1550 - 1630 | U.S. Air Force: Air Force Existing and Potential Needs and Requirements, Maj. Gen. Maxson |
| 1630 - 1710 | U.S. Army: Army V/STOL Roles and Missions |
| 1710 | ADJOURN |

Thursday, 28 June 1979

Subject Area Number Four: Review

Participants: DSB Task Force members and persons designated by the Chairman

| Time | Briefing |
|---|---|
| 0800 - 1200 | Reserved for any briefing of additional material generated as a need by previous briefings. (The Chairman will indicate at the end of each day which briefers are requested to remain for additional discussion.) |
| 1200 - 1300 | LUNCH |
| 1300 - 1700 | DSB Task Force subcommittee meet for analysis of material presented. |

Friday, 29 June 1979

Subject Area Number Five: Review and Development of Initial Conclusions and Recommendations

Participants: DSB Task Force Members

| Time | Briefing |
|---|---|
| 0800 - 0840 | Report of the Subcommittee on Technology, Chairman: Dr. Roberts |
| 0840 - 0920 | Report of the Subcommittee on Configurations: Chairman: Mr. Kuhn |
| 0920 - 1000 | Report of the Subcommittee on Mission Needs for V/STOL-Type Aircraft and Launch Platforms |
| 1000 - 1010 | BREAK |
| 1010 - 1130 | General Discussion |
| 1130 - 1210 | Chairman's Overview and Guidance on Preparation of the Draft Report |
| 1210 | ADJOURN |

# APPENDIX C

# SUPPORT DATA

# APPENDIX C

## Support Data

The supporting data contained in this appendix has been selected as representative of the large volume of data presented to the Defense Science Board Task Force on V/STOL Aircraft, Phase II. No attempt has been made to represent portions of each brief, each concept, or each technology. Rather the charts were selected for the following reasons:

1. Identification of primary issues
2. Value to the Task Force
3. Support to the conclusions and recommendations
4. Value in providing general V/STOL information

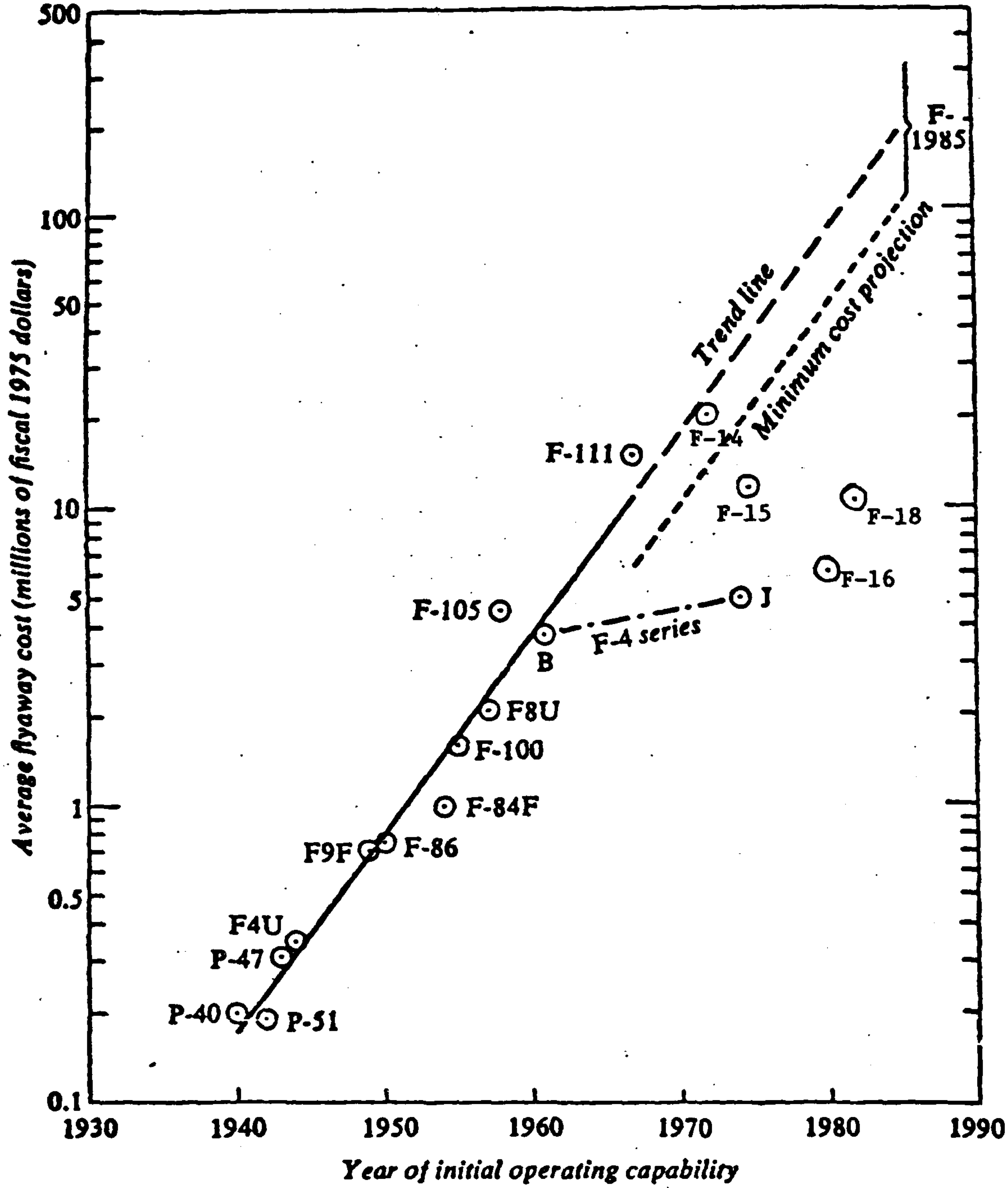
All data presented to the Defense Science Board Task Force is considered to be released from proprietary restrictions, however, unclassified material should be handled on a need-to-know basis.

## INDEX TO SUPPORTING DATA

## Supporting Data

## General Information

**Trend in Unit Cost of U.S. Fighter Designs**[a]




a. Costs are plotted on a semilogarithmic scale to facilitate discrimination among the earlier aircraft. A trend line for 1940–67 is fitted by the method of least squares. This line is projected through 1980 along with the minimum cost associated with it at a statistical level of confidence of 95 percent.

COST RATIOS FOR DISPERSAL

| | INVESTMENT COSTS | O & S |
|---|---|---|
| CTOL | 1.0 | 1.0 |
| STOL | 1.069 | 1.064 |
| STOVL | 1.088 | 1.114 |
| V/STOL | 1.183 | 1.188 |

# CNO SEA BASED AIR MASTER STUDY PLAN

## CURRENT STUDIES

| | |
|---|---|
| • AIRCRAFT ALTERNATIVES | - V/STOL<br>- STOVL<br>- STOL<br>- CTOL |
| • CILOP | - CILOP |
| • COMMISSIONED SHIPS | - PRIMARY AVIATION SHIPS<br>- AIR CAPABLE SHIPS |
| • COMMERCIAL AVIATION SHIPS | - COMMERCIAL AVIATION SHIPS |
| • AIR LAUNCHED WEAPONS | - AIR LAUNCHED WEAPONS |
| • SHIP LAUNCHED/SLAT WEAPONS | - SHIP LAUNCHED/SLAT WEAPONS |
| • MARITIME PATROL AIRCRAFT | - LAND BASED NAVAL AIR |
| • C3 | - C3 |
| • LOGISTICS | - LOGISTICS |
| • DISTRIBUTED FORCES CONCEPTS | - V/STOL OPS CON<br>- STOVL OPS CON<br>- STOL OPS CON<br>- CTOL OPS CON |
| • ANALYSIS AND COMPARISON OF ALTERNATIVE SEA BASED AIR FORCES | - FORCE REQUIREMENTS AND EMPLOYMENT<br>- FORCE LEVELS<br>- TRANSITION PLAN<br>- INVENTORY COST AND COST EFFECTIVENESS |

## PRELIMINARY INDICATIONS

## NAVY SEA-BASED AIR-MASTER PLAN

- V/STOL LARGER, HEAVIER AND MORE EXPENSIVE THAN CTOL
- AIR CAPABLE SHIPS WITH FEWER THAN 5 OR 6 AIRCRAFT NOT COST EFFECTIVE (EXCEPT LAMPS)
- STOL OPERATIONS IMPRACTICAL ON CAVS (V/STOL AND STOVL ONLY)
- IMPROVEMENTS REQUIRED IN AIRBORNE RADAR AND TERMINAL SEEKER FOR SLAT
- FOLLOW-ON MPA WILL BE EXPENSIVE. WILL NEED STUDIES ON TRADEOFFS BETWEEN MPA/SBA
- REQUIRE INCREASED ELOS COMMUNICATIONS AND DATA PROCESSING CAPABILITY
- INCREASED LOGISTICS COSTS DUE TO DISPERSAL
- EFFECTIVENESS OF DISPERSAL IS EXTREMELY SENSITIVE TO SCENARIO ASSUMPTIONS ON ENEMY TARGET CAPABILITY AND U.S. WEAPONS EFFECTIVENESS

## $C^3$ AREAS OF CONCERN

1. AIR CONTROL/INCREASED PLATFORMS
2. LOGISTICS CONTROL
3. ELECTRONIC EMISSION CONTROL
4. SLAT CONTROL
5. EXTENDED LINE-OF-SIGHT COMMUNICATIONS
6. DISPERSED COMMAND AND CONTROL

## LOGISTIC EFFICIENCY

- NORMALIZED TO AV-8B IN NORTH EUROPE

| FACTOR | AIRCRAFT | SCENARIO NORTH EUROPE | PERSIAN GULF | KOREA |
|---|---|---|---|---|
| O TARGETS DESTROYED/GAL X 1000 | A-4/AV-8A | 0.6 | 0.5 | 0.5 |
| | F/A-18 | 0.5 | 0.6 | 0.4 |
| | AV-8B | 1.0 | 1.1 | 0.9 |
| O TARGETS DESTROYED/TON | A-4/AV-8A | 0.8 | 0.7 | 0.6 |
| | F/A-18 | 0.9 | 1.2 | 0.9 |
| | AV-8B | 1.0 | 1.2 | 0.9 |
| O TON/GAL X 1000 | A-4/AV-8A | 0.7 | 0.7 | 0.7 |
| | F/A-18 | 0.5 | 0.5 | 0.5 |
| | AV-8B | 1.0 | 1.0 | 1.0 |

## BASING FEASIBILITY

- O BASING REQUIREMENTS SCENARIO DEPENDENT
- O V/STOL FORWARD BASE CONSTRUCTION REQUIREMENTS DEPENDENT ON AVAILABILITY OF EXISTING FACILITIES (ROADS, GRASS FIELDS) THAT CAN SUPPORT V/STOL OPS
- O V/STOL OPERATIONS FEASIBLE FROM CV, AMPHIBIOUS OR MODIFIED MSC SHIPS AND BARGES
- O ASSAULT ECHELON OF AMPHIBIOUS SHIPPING CAN CARRY MATERIAL AND EQUIPMENT TO CONSTRUCT A V/STOL FACILITY (1000'x72' RUNWAY W/100000 $FT^2$ OF PARKING, TAXIWAYS AND LIGHTING)

## PROVEN ADVANTAGES OF VSTOL LIGHT ATTACK AIRCRAFT

The basic advantage of a VSTOL capability is increased combat versatility. The U. S. Marine Corps has developed the VSTOL concept and has this versatility organic within its light attack forces. The advantages resulting from VSTOL aircraft and their integration into the Corps are included in the following listing.

### OPERATIONAL ADVANTAGES

- Operate anywhere, land anytime, on time, routinely and safely, within established regulations, including:
  - Forward area sites in close support of ground troops
  - Amphibious ships in close support of beachhead forces
  - Aircraft carriers and platform decks as optional basing during amphibious operations
  - Conventional bases even if runways have been damaged
  - Remote concealed sites for dispersion
  - Road segments or other austere sites for convenience and economy
  - Operate with a 300 ft ceiling and 3/4 nm visibility at sea (CCA available)
- Concentration or dispersal of forces
  - Under 2 minutes scramble time
  - 11 minute response time
  - 1400 nm unrefueled ferry range, 600 gallons of external fuel
  - Jet cruise speeds
  - Air refueling for long distance ferry
  - Initial supply by helicopter, routine supply by truck, rail, etc.
  - Ability to operate at sea or ashore for extended tours of duty
  - Austere site operation; grass strip, woods, roads, etc.
- Economy of Forces
  - Ground rather than air loiter
  - High sortie rate - Max. 10/day
  - Self defensive operations permitted without air cover in emergency situations

ITEM

- Conservation of Energy
  - Ground loiter saves fuel, lubricants, and wear and tear
  - No EAF required - saves men, equipment, fuel and facilities
  - Short mission legs due to forward basing saves provisioning and supply of fuel

- Attack Force Efficiency
  - High sortie rate
  - Quick response time

  - High total ordnance on target
  - Harrier Trainer Combat Capable

- Self-Defense Capability
  - Emergency operations in hostile environment are permitted without air cover
  - AV-8A is small, emits negligible smoke and is hard to detect, particularly in look down
  - Thrust vectoring provides maneuverability and speed agility
  - Excellent AIM-9 (Sidewinder) capability with SEAM

- Safety Aspects
  - Incorporates built-in-test philosophy
  - Outstanding safety record
  - In wingborne flight near stall, departure is in roll and the aircraft is highly spin resistant
  - Slow takeoff and landing speeds
  - Land anywhere - afloat or ashore (within established regulations)

- Survivability
  - Dispersal capability to many sites
  - High speed target penetration, good low altitude riding qualities
  - Thrust vectoring for speed control and turn rate results in decreased threat exposure
  - Ground loiter provides less exposure than air loiter
  - Thrust vectoring used in jinking maneuvers provides an evasive flight path through ground based defenses

ITEM

- o High Target Effectiveness
  - o Optimum speed attack
  - o High angle attack
  - o Thrust vectoring for flight path control
  - o Ability to carry and deliver a wide range of ordnance for many different targets
  - o Quick response to support ground forces in transient situations
  - o Twin 30mm cannon

- o Improves the Marine Corps Air/Ground Concept
  - o Fixed wing aircraft and helicopter have common basing capabilities
  - o Simplifies command and control
  - o Does not require EAF or other elaborate base equipment
  - o Will provide helicopter support and fire suppression

CONCEPT ADVANTAGES

- o Improved Response/Sortie Rate
  - o Based near conflict area
  - o Short sortie duration
  - o Good target opportunities
  - o Handle peak request rate
  - o Responsive to Marine ground forces potential deployment scenarios
  - o Closer integration of helicopter/fixed wing attack forces
  - o Responsive to other missions and tasks

- o AV-8A is Capable of Other Missions
  - o Tactical Air Controller (Airborne)
  - o Armed Reconnaissance/Observation
  - o Interdiction
  - o Deck Launch Intercept
  - o Anti-Submarine Warfare (ASW)

TECHNOLOGICAL ADVANTAGES

- o Thrust vectoring control for take off, inflight and landing
- o High thrust to weight ratio in combat
- o Good specific fuel consumption at high power settings
- o Small, simple aircraft
- o Integral start capability and APU
- o Versatile short takeoff aircraft with payload increasing rapidly with increased takeoff distance
- o Reaction control system provided for hovering, slow speed flight, and in air combat
- o Turbofan engine sized for landing/takeoff and combat

## TECHNOLOGICAL ADVANTAGES (Continued)

- o Engine optimized for VSTOL
  - o Countet rotating spools eliminate gyroscopic forces
  - o Overspeed provides lift thrust ratings for vertical flight
  - o Water injection restores thrust at hight temperatures
- o Stable but agile bomb delivery platform
- o Unique all-ship suitability is due to the landing and takeoff agility with thrust vectoring (no catapult or arresting gear used)
- o Air transportable by CH-53
- o Direct lift control
  - o Inflight
  - o Landing and takeoff
- o Ski-jump capability

## ADDITIONAL ADVANTAGES WITH AV-8B

- o More payload for same radius
- o More radius for same payload
- o Unrefueled ferry from West Coast to Hawaii
- o More vertical lift
- o Reduced STO distance
- o More accurate weapon delivery
- o Improved flight handling qualities
- o Reduced pilot workload
- o Head-up TVC use in ACM
- o Increased Reliability
- o Decreased Maintenance
- o Survivability enhancement features
- o Technology advances
  - o Lift improvement devices
  - o Composite structure (wing and forward fuselage)
  - o Supercritical wing airfoils

UNITED KINGDOM MINISTRY OF DEFENCE BRIEFING FOR US DEFENSE SCIENCE BOARD TASK FORCE ON VSTOL, PHASE II.
WOODS HOLE, MASSACHUSETTS, WEDNESDAY, JUNE 27, 1979.

---

UNITED KINGDOM OPERATIONAL EXPERIENCE WITH HARRIER AND FUTURE VSTOL MISSION POSSIBILITIES.

Introduction

Mr Chairman, Gentlemen.

1. My name is Don Harper and I am Deputy Chief Scientist, Royal Air Force, and I also have responsibilities in the management of aircraft research for all three United Kingdom Services. I have been associated with VSTOL aircraft technology for over twenty years.

2. I want to say just a very few words by way of introduction to this presentation. The United Kingdom Ministry of Defence very much appreciates this opportunity to appear before you. We believe we have something unique to offer in addressing your subject and in particular what I take to be perhaps the key point in the Memorandum sent you by the Under Secretary of Defense, Research and Engineering. I quote - "The preferred question is, what are the real naval/military uses of VSTOL based on current and feasible future technology, etc," unquote.

3. The British experience with fixed-wing VSTOL aircraft has been based on just that approach; we foresaw the vulnerability of large bases on land and at sea, we evolved the vectored-thrust aircraft technology and we have devised military uses, both ship and shore based, of such an aircraft, the British Aerospace Harrier, which you know better, perhaps, as the AV-8A, and we are now in the course of projecting forward possible expansions of such uses based on feasible future technology. Air Commodore Merriman, of the Royal

Air Force, will first describe the RAF's experience and thinking for the future and he will be followed by Commander Milner, Royal Navy, who will cover similar ground from the Royal Navy's point of view. These presentations contain material up to Secret level. Gentlemen, may I introduce Air Commodore Merriman.

------oOo------

Concluding Remarks

1. Mr Chairman, Gentlemen. I want to make one final point. Cdr Milner mentioned the commonly held view that VSTOL aircraft do not have the performance of conventional aircraft. This is something of a myth as far as vectored-thrust VSTOL aircraft are concerned. If the runway length needed by conventional aircraft is available, vectored-thrust VSTOL aircraft can be operated conventionally and, up to the limit of their weapon attachment points' capacity, can have similar payload/range performance as an otherwise equivalent conventional aircraft. The vectored-thrust VSTOL aircraft, however, can continue to operate, with reduced payload or range, when operating surface length becomes too short for conventional aircraft to operate at all.

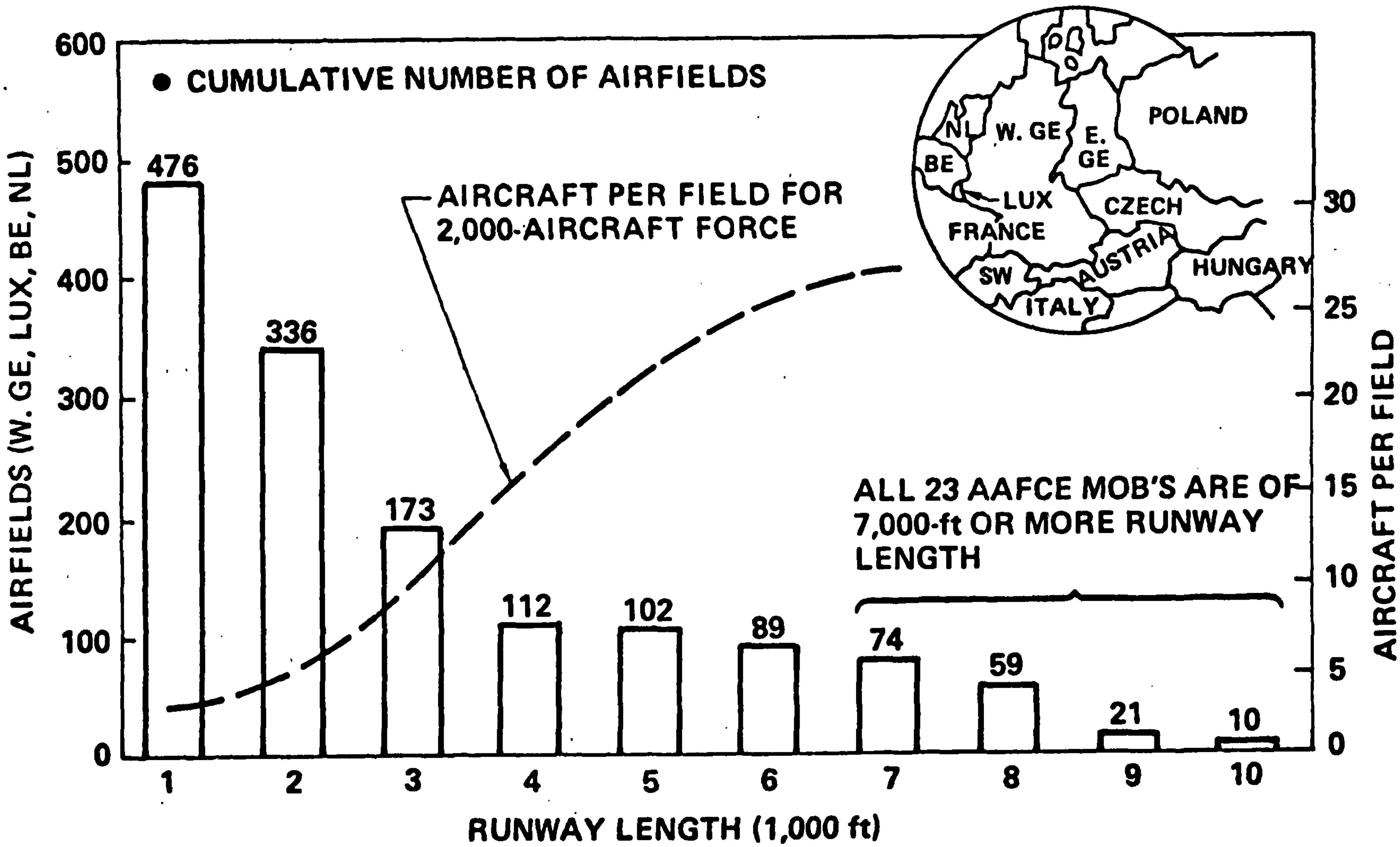
2. I hope this necessarily brief overview of the UK's VSTOL experience and thinking for the future has been helpful to you in your task. We should very much welcome further discussion tomorrow should you require it, for example, perhaps to touch more than we have had time for today on possible technological developments and to go into more detail on operational aspects for the future. Also, the fourth member of our team here today, Mr Frank Wood of our

Defence Equipment Staff in Washington DC will be pleased to try to provide anwers to any further questions which might arise when you return to your offices. It might be convenient, perhaps to channel these through your Executive Secretary. Thank you, gentlemen.

Supporting Data

Missions

# Dispersed Basing



# WHY V/STOL?

- LARGE AIR BASES MAY NOT BE AVAILABLE IN OBJECTIVE AREA
- QUICK RESPONSIVENESS REQUIRED TO SUPPORT GROUND COMMANDER
- INTERDICTION THREAT ON LAND TO CTOL AIRCRAFT CONSTRAINED TO LARGE AIR BASES
- CONSTRAINED OPERATIONS OF CTOL AIRCRAFT AIR POWER AT SEA
- V/STOL PERMITS TAILORING OF FORCE TO MEET SPECIFIC THREATS

33-77

# TACTICAL V/STOL

- TACTICAL V/STOL AIRCRAFT ARE FEASIBLE

  AV8A/AV8B
  YAK-36

- THE ISSUES ARE TACTICAL USEFULNESS COMPARED TO OTHER APPROACHES AND AFFORDABILITY

- CONCEPT OF OPERATIONS DEFINITION MUST BE INTEGRATED WITH TECHNOLOGY PLANNING TO AVOID MIS-MATCH. NEED TO CONVERGE CONFIGURATIONS/TECHNOLOGY SETS

- DEFINE RELATED SPECIFIC TECHNOLOGY CHALLENGES AND NEEDS

# SUMMARY OF NORTHROP VIEWS

V/STOL ON SMALLER SHIPS PROVIDES FORCE DISPERSAL AND INCREASED PRESENCE

EFFICIENCY OF FLEET DEFENSE AIR OPERATIONS IMPROVED BY VTOL OPERATION FROM FORWARD DEPLOYED DLI SHIPS

PERFORMANCE AND COST GAP BETWEEN V/STOL AND CTOL FIGHTER/ATTACK AIRCRAFT REDUCING

- SYSTEM PERFORMANCE REQUIREMENTS
- TECHNOLOGY ADVANCEMENTS

IF DISPERSION OF FLEET RESOURCES IS SHOWN TO BE COST/EFFECTIVE

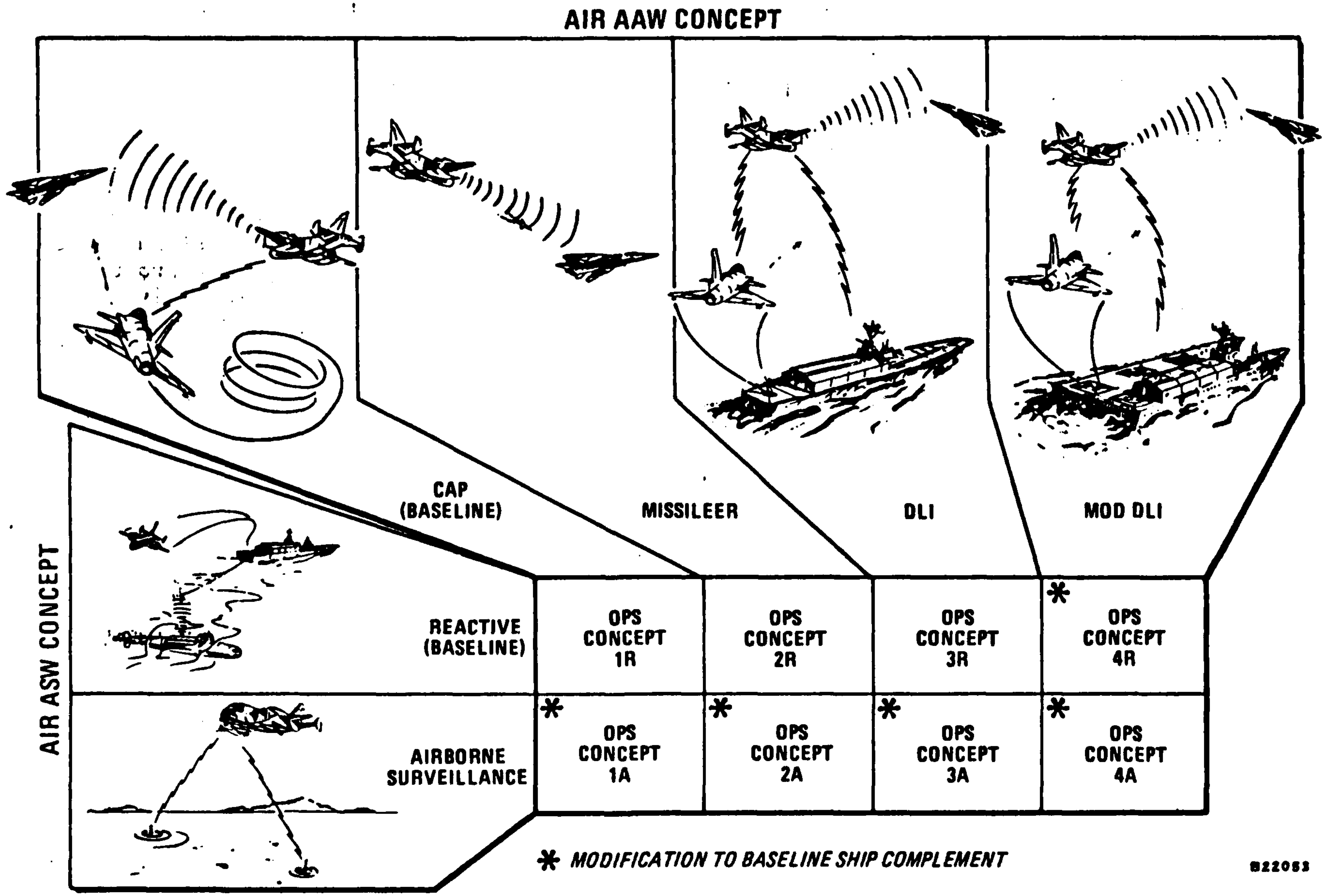
- FOCUS TECHNOLOGY DEVELOPMENT PROGRAM
- RE-VALIDATE DURING TECHNOLOGY DEVELOPMENT PROCESS

79-12986B
3P

# OPERATIONAL CONCEPT ALTERNATIVES

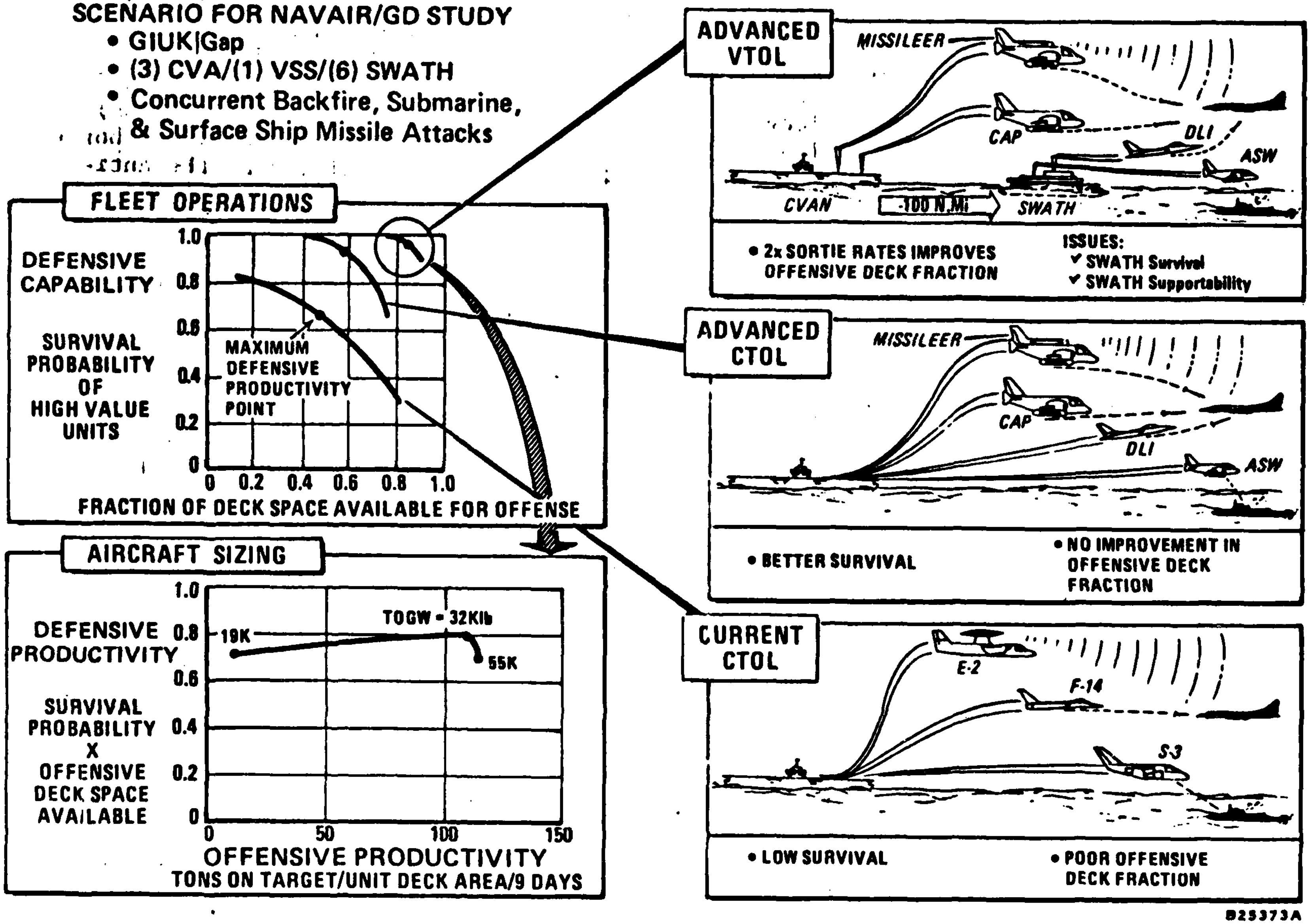
SCENARIO 1

MAJOR SEA-AIR BATTLE – NORTH ATLANTIC



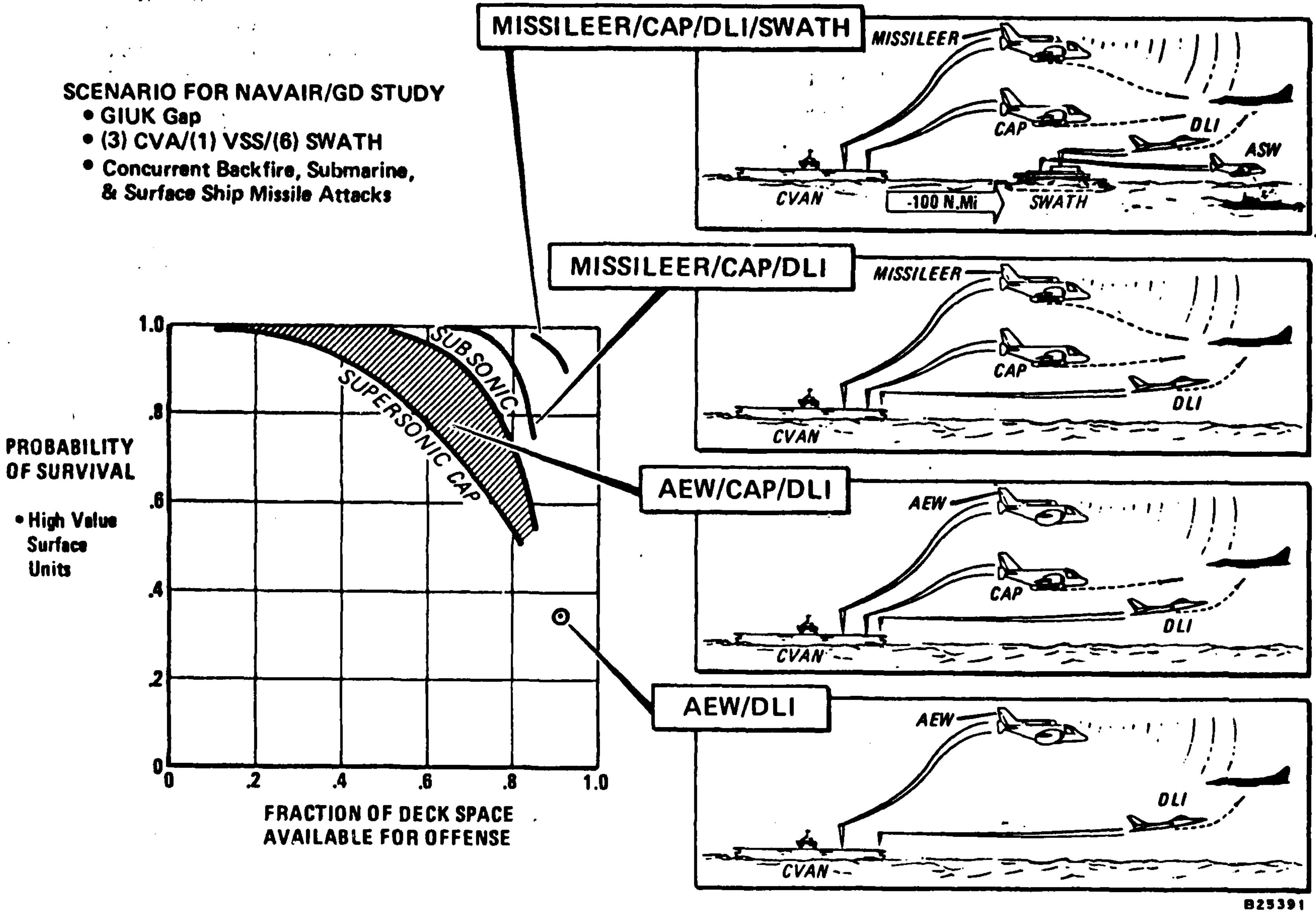
# V/STOL-OFFERS LARGE POTENTIAL IN FLEET DEFENSE

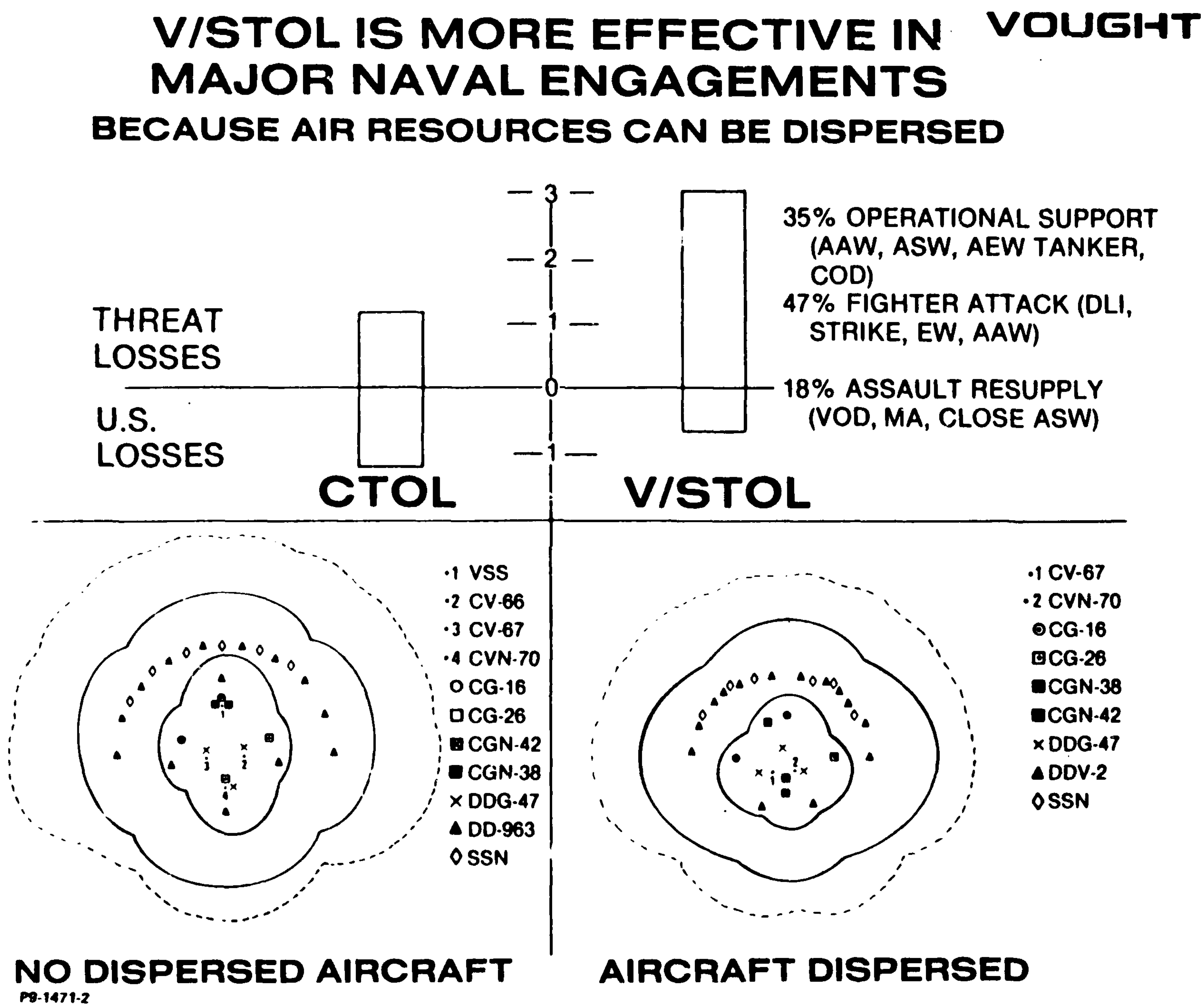
SCENARIO FOR NAVAIR/GD STUDY
- GIUK|Gap
- (3) CVA/(1) VSS/(6) SWATH
- Concurrent Backfire, Submarine, & Surface Ship Missile Attacks



# MISSILEER AND DLI DISPERSAL CAPITALIZE ON V/STOL POTENTIAL

SCENARIO FOR NAVAIR/GD STUDY
- GIUK Gap
- (3) CVA/(1) VSS/(6) SWATH
- Concurrent Backfire, Submarine, & Surface Ship Missile Attacks

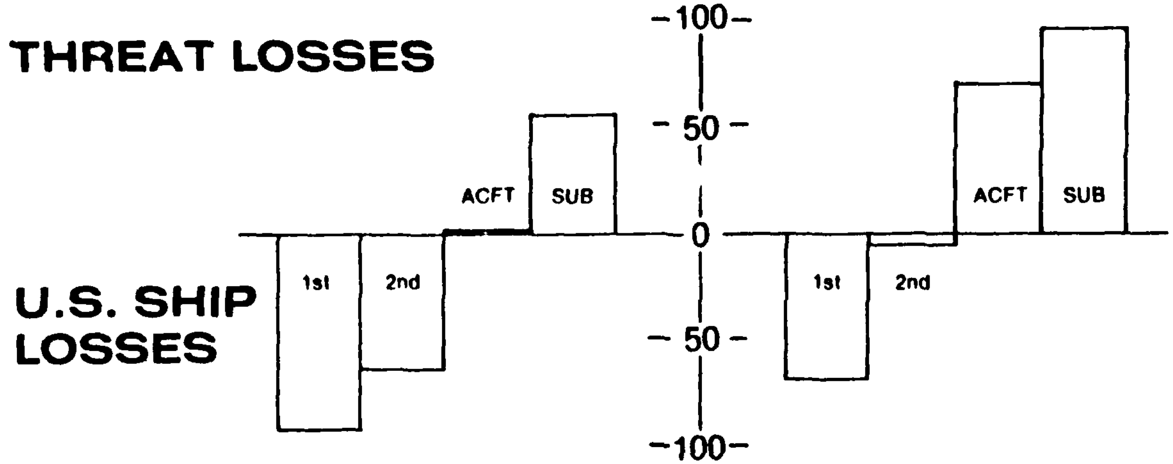


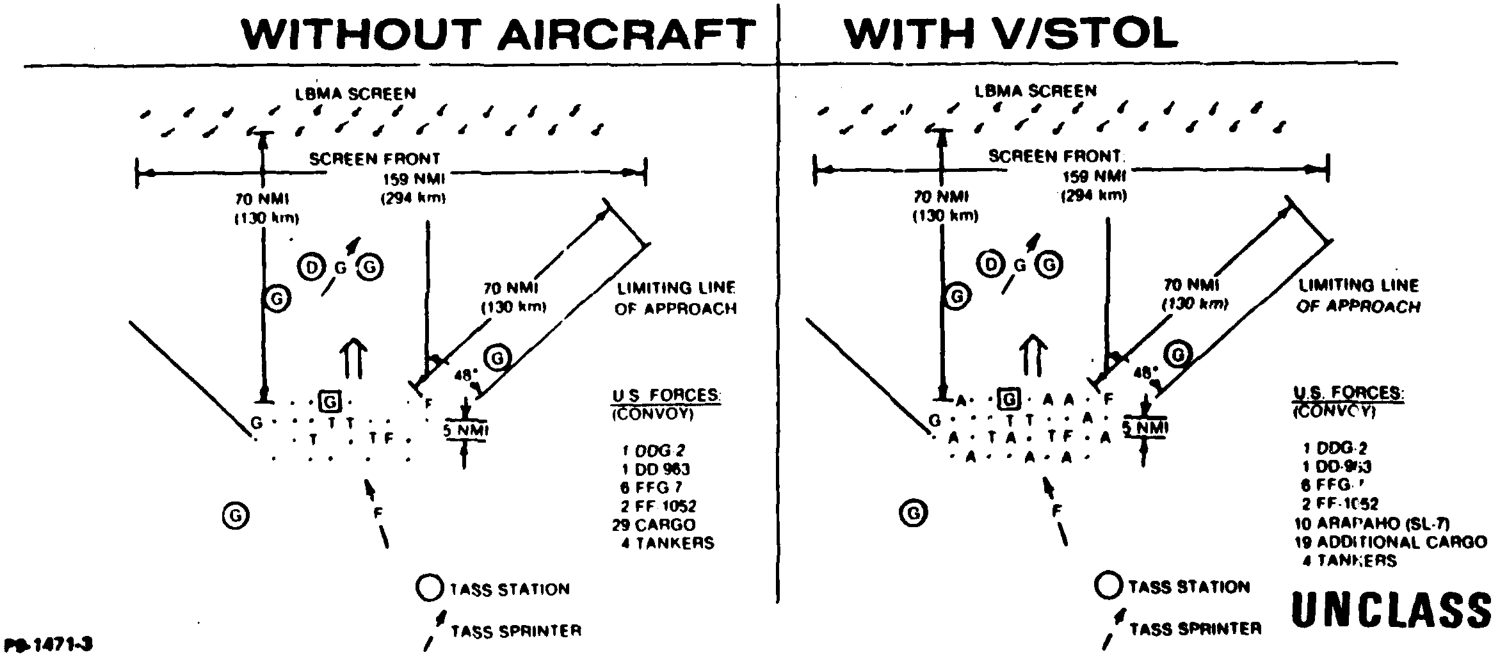

V/STOL IS MORE EFFECTIVE IN MAJOR NAVAL ENGAGEMENTS
VOUGHT
BECAUSE AIR RESOURCES CAN BE DISPERSED
THREAT LOSSES
U.S. LOSSES
3
2
1
0
-1
35% OPERATIONAL SUPPORT (AAW, ASW, AEW TANKER, COD)
47% FIGHTER ATTACK (DLI, STRIKE, EW, AAW)
18% ASSAULT RESUPPLY (VOD, MA, CLOSE ASW)
CTOL
V/STOL
•1 VSS
•2 CV-66
•3 CV-67
•4 CVN-70
CG-16
CG-26
CGN-42
CGN-38
DDG-47
DD-963
SSN
•1 CV-67
•2 CVN-70
CG-16
CG-26
CGN-38
CGN-42
DDG-47
DDV-2
SSN
NO DISPERSED AIRCRAFT
AIRCRAFT DISPERSED
P8-1471-2

UNCLASSIFIED

VOUGHT

# V/STOL CAN ADD EFFECTIVE AIR ASSETS TO CONVOYS




P8-1471-3

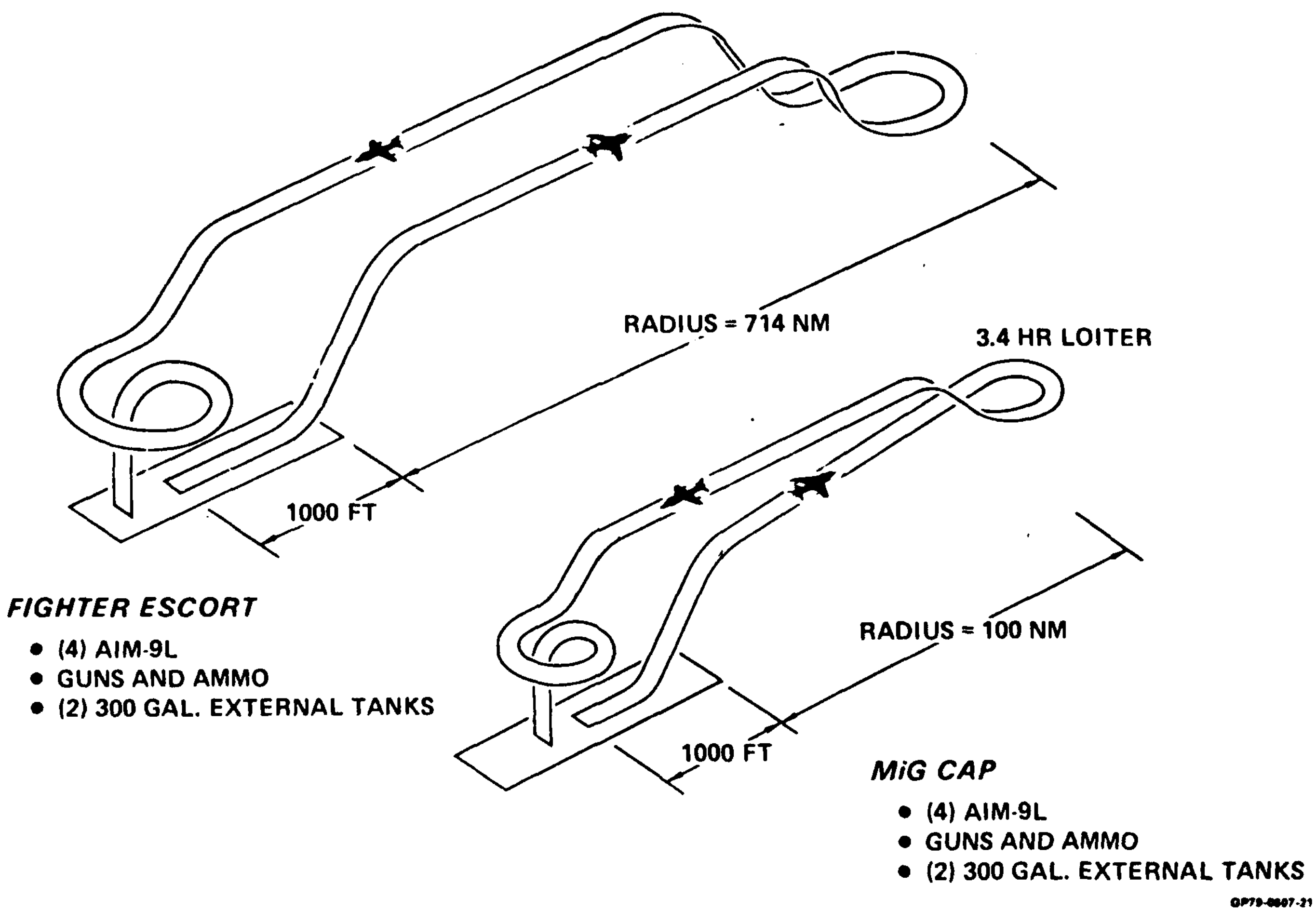
UNCLASSIFIED

# POTENTIAL V/STOL FIGHTER/ATTACK PAYOFFS

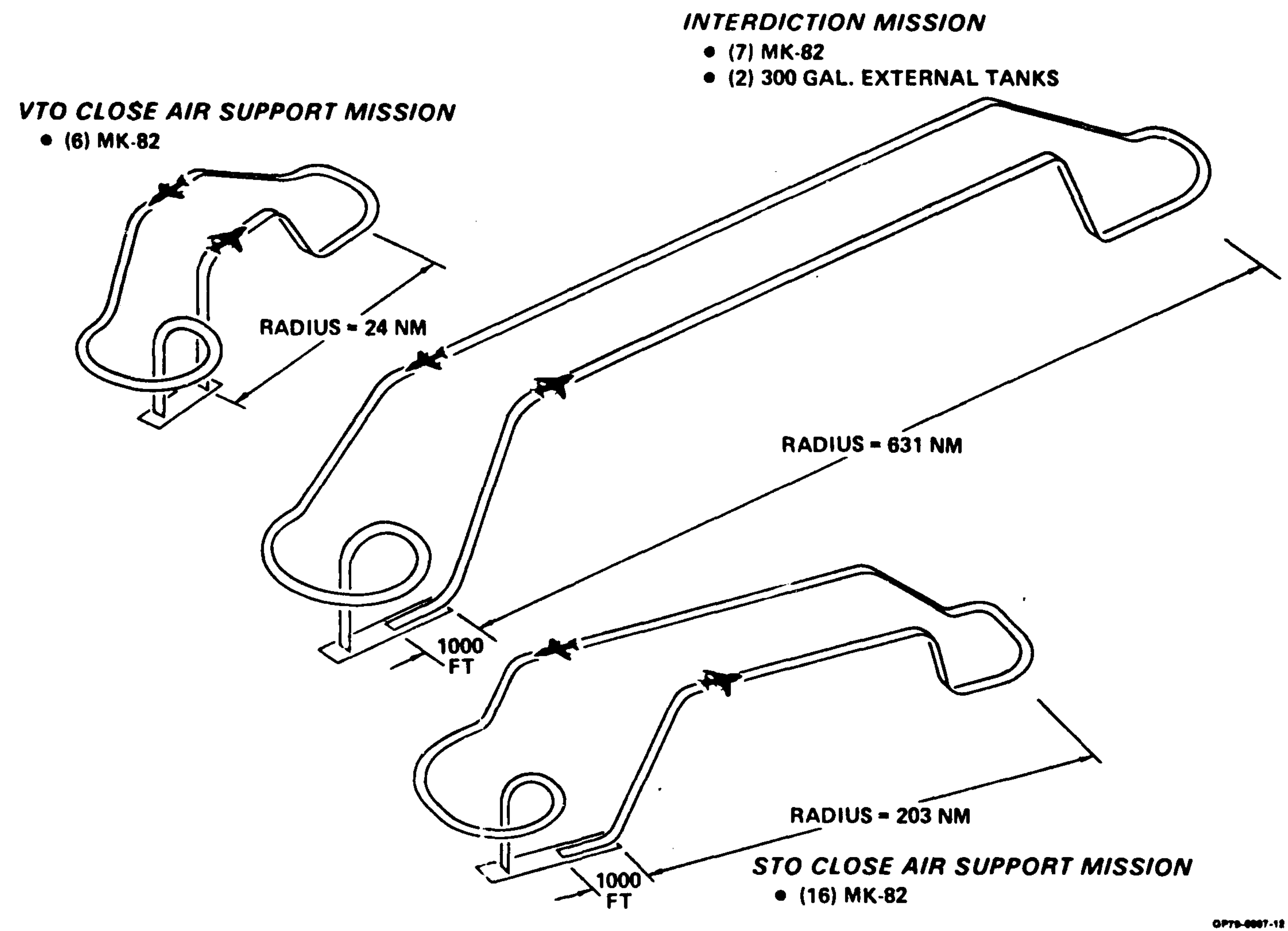
| | | |
|---|---|---|
| FLEET MISSIONS | CONVOY PROTECTION | ADDS AIR & SURFACE DEFENSE/EW/RECCE CAPABILITIES |
| | • POWER PROJECTION<br>• AMPHIBIOUS ASSAULT | SOME PAYOFF |
| FLEET DEFENSE | AIR THREAT | ENHANCED THROUGH DECK-LAUNCHED INTERCEPT FROM FORWARD DEPLOYED SHIP |
| | SURFACE THREAT | ENHANCED THROUGH QUICK RESPONSE FROM FORWARD DEPLOYED SHIP |

79-12977A
3P

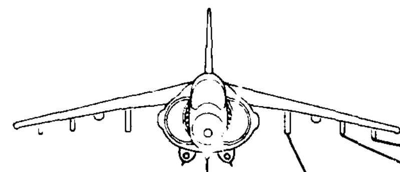
# AIR-TO-AIR CAPABILITY (U)



# ATTACK CAPABILITY (U)



# AV-8B STORES CAPABILITY (U)



| STORES | MAX UNIT WT (LB) | CENTER PYLON (1000 LB) | INBOARD PYLON (2000 LB) | INTERMEDIATE PYLON (1000 LB) | OUTBOARD PYLON (630 LB) | TOTAL PER AIRCRAFT |
|---|---|---|---|---|---|---|
| MISSILES | | | | | | |
| AIM-9H/L SIDEWINDER | 197 | – | – | 1 | 1 | 4 |
| AGM-65/E LASER GUIDED MAVERICK | 465 | – | 1 | 1 | – | 4 |
| TOMAHAWK (GROWTH) | 2750 | – | 1(1) | – | – | 2 |
| AGM-88 HARM (GROWTH) | 730 | – | 1 | 1 | – | 4 |
| WALLEYE I ERDL(2) | 1224 | – | 1 | – | – | 2 |
| GENERAL PURPOSE BOMBS | | | | | | |
| MK-81 LDGP CONICAL FIN | 260 | 2 | 3 | 3 | 1 | 16 |
| MK-81 SNAKEYE | 300 | 2 | 3 | 3 | 1 | 16 |
| MK-82 LDGP CONICAL FIN | 531 | 2 | 3 | 3(1) | 1 | 16 |
| MK-82 SNAKEYE | 570 | 2 | 3 | 3(1) | 1 | 16 |
| MK-83 LDGP CONICAL FIN | 985 | - | 2 | 1 | - | 6 |
| DESTRUCTORS (MINES) | | | | | | |
| MK-36 MODS 1A, 2, 3, 4 (MK-82 BODY) CONICAL FIN | 531 | 2 | 3 | 3(1) | 1 | 16 |
| MK-36 MODS 1A, 2, 3, 4 (MK-82 BODY) S E HIGH DRAG/LOW DRAG | 570 | 2 | 3 | 3(1) | 1 | 16 |
| MK-40 MODS 1A, 2, 3, 4 (MK-83 BODY) CONICAL FIN | 985 | – | 2 | 1 | – | 6 |
| MK-40 MODS 1A, 2, 3, 4 (MK-83 BODY) S E HIGH DRAG/LOW DRAG | 1105 | – | 2 | 1 | – | 6 |

(1) Carriage at reduced load factor.
(2) AWW-7A Walleye Extended Range Data Link (ERDL) pod used as required.

GP79-0607-9

## CONCLUSIONS/SUMMARY

## V/STOL EFFECTIVENESS

- V/STOL OR STOL MAY PROVIDE ENHANCED FORCE SURVIVABILITY AND POST-ATTACK EFFECTIVENESS.
- STOL AND V/STOL PROVIDE FLEXIBLE BASING CONCEPTS. AIR FORCE UTILIZATION (V/STOL vs STOL) NEEDS CLARIFICATION.
- RELATIVE TO A CTOL VEHICLE OF EQUAL MISSION CAPABILITY, V/STOL WILL HAVE WEIGHT AND COMPLEXITY PENALTIES, <u>BUT</u> ADDED MISSION FLEXIBILITY AND CAPABILITY MUST ALSO BE CONSIDERED.
- CRITICAL REQUIREMENTS SUCH AS ONE ENGINE-OUT CAPABILITY, EXTENDED HOVER, ETC. MUST BE CAREFULLY WEIGHED BECAUSE THEY WILL DRIVE THE SYSTEM.
- PROPULSION, AERODYNAMICS, AND CONTROL ARE KEY TECHNOLOGIES. THEIR DEVELOPMENT AND INTEGRATION WILL DETERMINE WHETHER PRACTICAL, AFFORDABLE ADVANCED V/STOL CONCEPTS CAN BE DEVELOPED.
- MANY AIR FORCE TECHNOLOGY BASE EFFORTS WILL BE OF DIRECT BENEFIT TO V/STOL AND STOL DEVELOPMENT.

## WHY V/STOL FOR THE MARINE CORPS?

- o DISPERSED FORCE FOR LAUNCHING AMPHIBIOUS ASSAULTS
- o EXPEDITIONARY CAPABILITY
    - INDEPENDENCE FROM FIXED AIRFIELDS
    - GREATLY REDUCED DEPENDENCE ON EXPEDITIONARY AIRFIELD (EAF) EQUIPMENT
- o BASING FLEXIBILITY
    - SHIPS
    - AUSTERE FORWARD BASES
- o GROUND BASE SURVIVABILITY
    - DETECTABILITY
    - VULNERABLE AREA
- o SHORTENED COMMAND, CONTROL LINKS
- o QUICKER RESPONSE WITH FUEL ECONOMY
- o NO SIGNIFICANT AIRCRAFT PERFORMANCE PENALTIES

NAVY V/STOL MISSIONS

DEFENSE SCIENCE BOARD

27 June 1979

Woods Hole, MA

I. SUBJECT AREA: Review of existing and potential mission needs that could be fulfilled by V/STOL type aircraft and launch platforms.

II. A. NAVY MISSION (TITLE 10, U.S.C.)

-- Prompt and sustained combat operations at sea in support of U.S. national interests

B. NAVY FUNCTIONS (DODD 5000.1)

-- Seek out and destroy enemy naval forces
-- Gain, maintain general naval supremacy
-- Control vital sea areas, protect vital SLOCs
-- Establish, maintain local sea, air superiority in area of naval operations
-- Seize and defend advanced naval bases

C. NAVAL FORCE CHARACTERISTICS

-- Mobile (geographic, political)
-- Flexible (in composition and capability)
-- Self supporting (ready on arrival)

III. FUNDAMENTAL WARFARE TASKS

° ANTIAIR WARFARE

- Air Superiority
- Air Defense

° ANTISURFACE WARFARE

- Distant Operations
- Close Operations

° ANTISUBMARINE WARFARE

- Distant Operations
- Close Operations

° MINE WARFARE

- Offensive
- Countermeasures

SUPPORTING WARFARE TASKS

° OCEAN SURVEILLANCE

° INTELLIGENCE

- Imagery
- Reconnaissance

° COMMAND, CONTROL, COMMUNICATIONS (C3)

° ELECTRONIC WARFARE

° LOGISTICS

- Long Haul Resupply
- Local Resupply
- Repair

| FUNDAMENTAL WARFARE TASKS | SUPPORTING WARFARE TASKS |
|---|---|
| ° <u>STRIKE WARFARE</u><br>- Nuclear<br>- Conventional<br>° <u>AMPHIBIOUS WARFARE</u><br>- Vertical Assault<br>- Over the Beach<br>- Close Support | |

IV. ° Manned, tactical sea based aircraft will continue to play a vital role in accomplishing the above missions, functions and tasks.

V. <u>WHY SEA BASED AIRCRAFT?</u>

-- Unique Capability to:

- Expand surveillance and weapons range
- Provide quick reaction, concentration of force
- Complement strengths and compensate for limitations in other platforms (ships, subs, "smart" weapons, satellites)

-- PLUS, the "person-in-the-loop" has proved indispensable in handling unprogrammed contingencies.

VI. <u>WHY V/STOL?</u>

° CTOL is great, <u>but</u>,

-- Wind over deck requirements limit ship maneuverability, SOA, screening force effectiveness
-- Launch and recovery operation requires large deck area, respots "foul the deck" for flight ops
-- CATS/arresting gear essential. Extremely reliable, but can be damaged.
-- Carrier proficiency requires fairly extensive, repeated training. Boarding rate sensitive to sea state.
-- Sea Based Air presence determined by number of carriers available.

° V/STOL largely overcomes CTOL limitations, provides equivalent combat performance.

* Nothing is free. V/STOL range-payload is less for equal cost, (or more expensive for equal range-payload). Logistic support cost is greater for dispersed vice concentrated aircraft.

## VII. V/STOL AIRCRAFT/PLATFORM POTENTIAL FOR FUTURE SEA BASED MISSION NEEDS

### A. ANTI-AIR WARFARE

-- V/STOL aircraft, platforms offer unrestricted launch, recovery operations in air defense. (This capability could be critical)

-- Forward basing of AEW, fighters increases warning time, DLI effectiveness. (Isolated platforms do not have mutual SAM support)

### B. ANTI-SURFACE WARFARE

-- V/STOL about the same as CTOL on CVBG strikes. CTOL may have greater range-payload, but advantage partially offset by lightweight, smart weapons. (Expense may limit weapons availability - undesirable, but is a conscious trade-off).

-- Main advantage is increased surveillance, OTHDC&T, and weapons delivery within non-carrier units. (ASM, SLAT)

### C. ANTI-SUBMARINE WARFARE

-- In multi-based formation, decreases aircraft required to maintain acoustic sensor field

-- Hover capability to deploy and recover acoustic arrays (not LAMPS mission)

-- Extends LAMPS coverage in non-carrier units

-- Provides deck launched vice airborne pouncer capability

-- V/STOL aircraft on merchant ships (CAVS) is unique V/STOL capability. Cost-effectiveness under study.

### D. MINE WARFARE

-- Weight/drag of current mine inventory limits V/STOL mine laying capability to short range or specialized missions

-- Mine sweep capability exists in low disc loading V/STOL designs. Main advantage is high transit speed.

E. STRIKE WARFARE

-- Similar to antisurface warfare
-- Addition of power projection capability, including RECCE, flexible targeting, and damage assessment to non-carrier units is a limited but significant new capability.

F. AMPHIBIOUS WARFARE

-- Again, quick response and basing flexibility are advantages. USMC rep will amplify.
-- Use of amphib platforms by V/STOL VF/VA when assault aircraft move ashore is an added advantage, but needs further development of logistics support.

G. INTELLIGENCE/SURVEILLANCE

-- Major V/STOL advantage accrues in non-carrier operations. Quick response, extended range and area coverage. Compensates for loss of capability during ship EMCON.

H. COMMAND, CONTROL, COMMUNICATIONS (C3)

-- OTH comms and data relay is not unique to V/STOL. Adding this capability to non-carrier units greatly increases effectiveness of all other missions. (ASW, ASUW, etc.)

I. ELECTRONIC WARFARE

-- System capabilities similar to advanced CTOL. Main advantage is quick response. Cover and deception potential is under study. (slow speed, hover mode)

J. LOGISTICS

-- VTOL (i.e. V/STOL)/STOVL capability, combined with basing, staging flexibility offers great potential for resupply to and within fleet units.
-- In the unfortunate event of battle damage to CTOL carrier, VOD of critical supplies/personnel can reduce repair times.

VIII. SUMMARY

° V/STOL acft/platform potential to meet Navy, Marine mission needs derives from fewer restrictions on

flight ops, basing flexibility, and highly capable mission performance based on advances in aircraft, weapons, and subsystems technology.

- Therefore, CTOL-V/STOL comparison cannot be made on basis of one-on-one aircraft flyoff.
- Basis for comparison is CNO Sea Based Air Master Study Plan.
- Regardless of outcome, DSB support of critical V/STOL technologies will benefit the eventual winner.

AIR FORCE
V/STOL MISSIONS

## AN AIR FORCE V/STOL FORMAL REQUIREMENT WILL:

- DEFINE V/STOL MISSIONS
- ACCESS THE VALUE OF V/STOL VERSUS STOL
- DETERMINE THE NEED FOR DISPERSED OPERATIONS
- DIRECT V/STOL INVESTMENT STRATEGY

## PROBLEMS OF TACTICAL AIR SURVIVABILITY

- CENTRALLY LOCATED AIR OPERATIONS
- LIMITED PASSIVE AIRFIELD PROTECTION
- WARSAW PACT CONVENTIONAL WEAPONS THREAT
- AIRFIELDS UNUSABLE FOR CTOL AIRCRAFT

## V/STOL REQUIREMENT

- NOT FORMALLY STATED
- NEED TO OPERATE FROM DAMAGED AIRFIELDS

# CURRENT TACTICAL AIR CAPABILITY

- SHORT TAKEOFF CAPABILITY

| | COMBAT WEIGHT |
|---|---|
| A 10 | 2700 FEET |
| F 15 | 1050 FEET |
| F 16 | 1300 FEET |

- LACK A SHORT FIELD LANDING CAPABILITY

| | MIN GROSS WEIGHT | MAX GROSS WEIGHT |
|---|---|---|
| A 10 | 1000 FEET | 1500 FEET |
| F 15 | 2600 FEET | 6200 FEET |
| F 16 | 2500 FEET | 3500 FEET |

- LIMITED RUNWAY REPAIR
- PORTABLE ARRESTING GEAR

# CONCLUSIONS

- STOL OR V/STOL COULD MEET THE REQUIRED CAPABILITY
- V/STOL POTENTIAL MISSIONS
- V/STOL OFFERS THE ADVANTAGES OF FLEXIBILITY AND SURVIVABILITY
- DESIGN LIMITATIONS DO NOT ALLOW V/STOL TO MEET ALL AIR FORCE MISSIONS

## REQUIRED TACTICAL AIR CAPABILITY

- INDEPENDENCE OF DAMAGED RUNWAYS
- EXTEND THE CAPABILITY OF OUR PRESENT FORCE STRUCTURE
- FUTURE AIRCRAFT MUST BE CAPABLE OF DISPERSED OPERATIONS

ARMY

MISSIONS/ROLES

ATTACK

SCOUT

UTILITY

MEDIUM LIFT

RECONNAISSANCE/SURVEILLANCE

(SPECIAL ELECTRONICS ROLE)

## POTENTIAL ADVANTAGES IN THE SEMA ROLE

AIRFIELD AVAILABILITY FOR CTOL AIRCRAFT

FLEET STANDARDIZATION

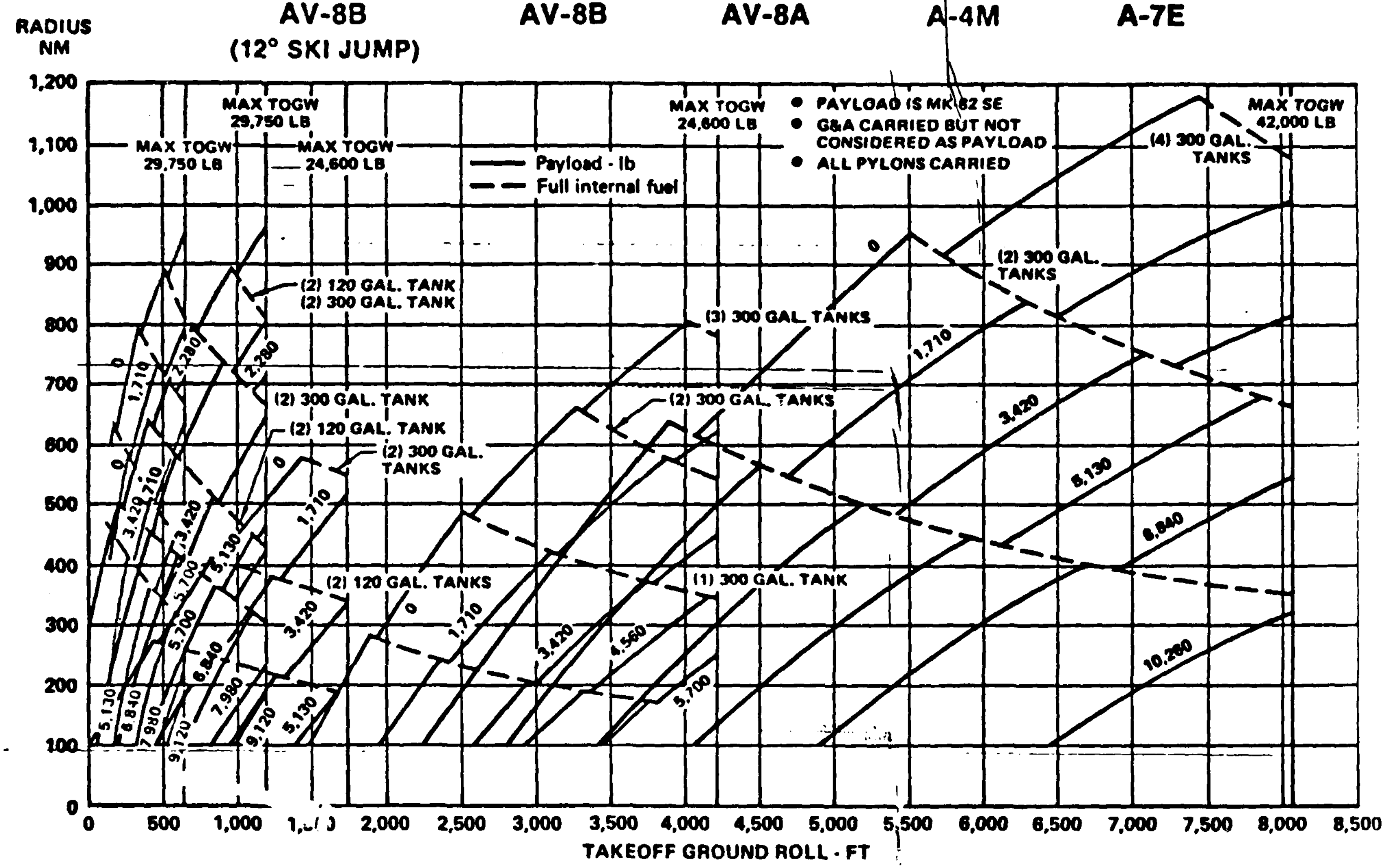
ENHANCED LOGISTICAL SUPPORT

MODULARIZED/PALLETIZED LOADS

DESIRABLE CHARACTERISTICS OF BOTH RW AND FW

LIFE EXPECTANCY OF CURRENT AIRFRAMES

# AV-8B, AV-8A, A-4M AND A-7E HI-LO-HI MISSION RADIUS vs TAKEOFF GROUND ROLL DISTANCE AND PAYLOAD

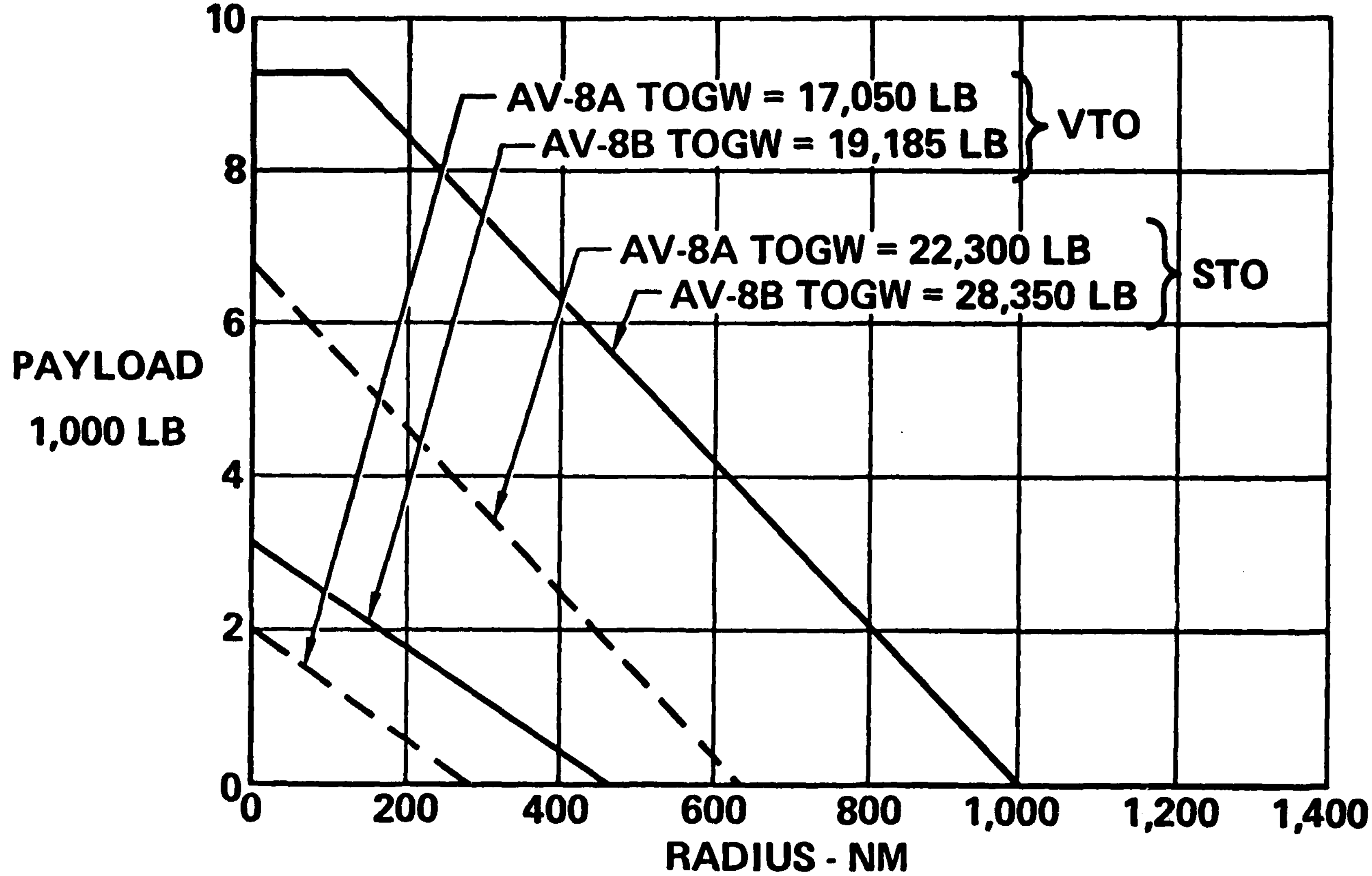



Notes:

1. Takeoff is at sea level at 90°F
2. Payload is MK-82 SE only
3. Guns and ammo carried on all missions but not considered payload
4. All pylons carried on all missions

# PAYLOAD - RADIUS COMPARISON

## INTERDICTION MISSION TROPICAL DAY



Supporting Data

Technology

## SUMMARY: STATE OF V/STOL TECHNOLOGY

- SUBSONIC V/STOL AIRCRAFT CONCEPTS
  - SOME READY FOR PRE-PRODUCTION PROTOTYPING
  - SOME REQUIRE MAJOR GROUND-BASED EFFORT AND/OR FLIGHT PROOF-OF-CONCEPT AS NEXT STEP
- SUPERSONIC V/STOL AIRCRAFT CONCEPTS
  - TECHNOLOGICAL BASE MUST BE EXPANDED TO ENABLE CONCEPT EVALUATION AND SELECTION
  - CONSIDERABLE DEVELOPMENT IS REQUIRED FOR A GIVEN CONCEPT
- GENERIC V/STOL R&D PROGRAM
  - ONGOING EFFORT IS MODEST, NEEDS TO BE INCREASED AND ACCELERATED
- V/STOL FACILITIES
  - GROUND FACILITIES ARE ESSENTIALLY ADEQUATE
  - NEED EXISTS FOR HIGH DISC LOADING FLIGHT RESEARCH FACILITIES

## STATE OF V/STOL AIRCRAFT TECHNOLOGY: JUNE 1979

| SUBSONIC CONCEPTS | EXAMPLE PERFORMANCE SPEED KT | ALTITUDE FT | RADIUS NM | TOS HR | READY FOR PRE-PRODUCTION PROTOTYPE? |
|---|---|---|---|---|---|
| ° ADVANCING BLADE | 250 | 25000 | 350 | 5.0 | YES |
| ° COMPOUND FIXED-WING HELICOPTER | 200 | 25000 | 400 | 4.5 | YES |
| ° TILT ROTOR | 350 | 35000 | 500 | 4.3 | YES |
| ° FOLDED AND/OR STOWED ROTOR | 450 | 35000+ | 475 | 4.3 | NO* |
| ° ROTOR-WING | 450 | 35000+ | 450 | 4.5 | NO** |
| ° PROPELLER-DRIVEN | 400 | 35000 | 600 | 4.1 | YES |
| ° LIFT/CRUISE FAN | 500 | 40000+ | 650 | 4.0 | NO** |
| ° THRUST AUGMENTING EJECTOR | 500+ | 45000 | 600 | 4.1 | NO* |
| ° DIRECT JET LIFT | 550+ | 50000 | 650 | 4.0 | EXISTS |

* NEED FULL-SCALE FLIGHT-TYPE SYSTEMS EFFORT

** NEED FLIGHT EXPERIENCE

## STATE OF SUBSONIC V/STOL AIRCRAFT TECHNOLOGY: JUNE 1979

| | EXAMPLE |
|---|---|
| • ADVANCING BLADE | XH-59 (1979) |
| • COMPOUND FIXED-WING HELICOPTER | RSRA (1979) |
| • TILT ROTOR | XV-15 (1979) |
| • FOLDED AND/OR STOWED ROTOR | FOLDED TILT ROTOR LARGE-SCALE, SEMISPAN, W.T. MODEL (1971) |
| • ROTOR-WING | X-WING LARGE-SCALE W.T. MODEL (1979) |
| • PROPELLER-DRIVEN | XC-142, X-22 (1960s) |
| • LIFT/CRUISE FAN | 3-FAN, LARGE-SCALE, 3-D W.T. MODEL (1979) |
| • THRUST AUGMENTING EJECTOR | XFV-12A (1979) |
| • DIRECT JET LIFT | YAV-8B (1979) |

# POTENTIAL TECHNOLOGY IMPROVEMENTS: SUBSONIC V/STOL AIRCRAFT CONCEPTS: JUNE 1979

| ° SUBSONIC CONCEPTS | POTENTIAL TECHNOLOGY IMPROVEMENTS |
|---|---|
| ° ADVANCING BLADE | COMPOUND PROPULSION SYSTEM & DRAG |
| ° COMPOUND FIXED-WING HELICOPTER | COMPOUND PROPULSION SYSTEM |
| ° TILT ROTOR | DIGITAL FBW & ACTIVE CONTROLS |
| ° FOLDED AND/OR STOWED ROTOR | FOLD SYSTEM & COMPOUND PROPULSION |
| ° ROTOR-WING | SYSTEMS INTEGRATION & DRAG |
| ° PROPELLER-DRIVEN | HOVER/TRANSITION CONTROL SYSTEM |
| ° LIFT/CRUISE FAN | SYSTEM INTEGRATION |
| ° THRUST AUGMENTING EJECTOR | AUGMENTATION RATIO |
| ° DIRECT JET LIFT | CONFIGURATION VARIANTS |

## STATE OF SUPERSONIC V/STOL AIRCRAFT TECHNOLOGY: JUNE 1979

- ADDITIONS TO THE TECHNOLOGY BASE ARE REQUIRED FOR EVALUATION AND SELECTION OF COMPETING CONCEPTS.

- ALL CONCEPTS LACK VERIFICATION FROM LARGE-SCALE GROUND-BASED EXPERIMENTAL ACTIVITIES AND FROM FLIGHT PROOF-OF-CONCEPT PROGRAMS.

- DISCIPLINARY AREAS REQUIRING EMPHASIS INCLUDE:
  - PROPULSION
  - LOW-SPEED CONTROL SYSTEMS
  - SUPERSONIC CRUISE EFFICIENCY
  - MANEUVERING FLIGHT
  - INTEGRATION

## POTENTIAL TECHNOLOGY IMPROVEMENTS: SUPERSONIC V/STOL AIRCRAFT CONCEPTS: JUNE 1979

| SUPERSONIC V/STOL AIRCRAFT CONCEPTS | POTENTIAL TECHNOLOGY IMPROVEMENTS |
|---|---|
| • LIFT/CRUISE ENGINE | PROPULSION SYSTEM & DRAG |
| • LIFT ENGINE (OR FAN) AND LIFT/CRUISE ENGINE | PROPULSION SYSTEM |
| • RALS + LIFT/CRUISE ENGINE | PROPULSION SYSTEM |
| • THRUST AUGMENTING EJECTOR | AUGMENTATION RATIO |
| • TILTING JET ENGINE | TRANSITION & PLATFORM ENVIRONMENT |
| • VERTICAL ATTITUDE | TRANSITION & PLATFORM ENVIRONMENT |

<u>SUPERSONIC V/STOL AIRCRAFT CONCEPTS</u>

- LIFT/CRUISE ENGINE
- LIFT ENGINE (OR FAN) AND LIFT/CRUISE ENGINE
- RALS + LIFT/CRUISE ENGINE
- THRUST AUGMENTING EJECTOR
- TILTING JET ENGINE
- VERTICAL ATTITUDE

## STATUS V/STOL NOZZLE TECHNOLOGY

- CURRENT ANALYTICAL EFFORT AND MODEL EXPERIMENTS DEVELOPING A BROAD TECHNOLOGY BASE FOR SUBSONIC V/STOL NOZZLES AND TO A MORE LIMITED EXTENT FOR SUPERSONIC V/STOL NOZZLES.
- PLANS FOR LARGE SCALE EVALUATION OF BETTER SUBSONIC V/STOL CONCEPTS.
- ADDITIONAL EFFORTS FOR SUPERSONIC V/STOL NOZZLES NEEDED.

## STATUS THRUST MODULATION TECHNOLOGY

- DEVELOPING ADEQUATE AERODYNAMIC TECHNOLOGY BASE FOR BOTH V.P. & VIGV FAN THRUST MODULATION CONCEPTS IN MODEL PROGRAM.
- LARGE SCALE EVALUATION OF VIGV CONCEPT IN PROGRESS, HOWEVER, ADDITIONAL WORK NEEDED.
- ADDITIONAL LARGE SCALE WORK NEEDED FOR VP FANS - PARTICULARLY IN REGARD TO LIGHT WEIGHT FOD RESISTANT FAN BLADES AND RELIABLE VARIABLE PITCH MECHANISMS.

## STATUS CONTROLS TECHNOLOGY

- DYNAMIC MODELING OF V/STOL PROPULSION SYSTEMS FOR STUDY OF AIRCRAFT HANDLING IN FLIGHT SIMULATORS IN PROGRESS.
- PLANS FOR STUDY OF CONTROL SYSTEM RELIABILITY IMPROVEMENT.
- ENGINE EVALUATION OF V/STOL PROPULSION CONTROL NEEDED.

## TRANSMISSION TECHNOLOGY

- HELICOPTER TRANSMISSION PROGRAM DEVELOPING BEARING AND GEARING TECHNOLOGY FOR HORSEPOWER LEVELS UP TO 3000.
- QCSEE PROGRAM DEMONSTRATED SPEED REDUCTION GEARING AT HORSEPOWER LEVELS OF 15,000.
- NEED TO DEMONSTRATE POWER TAKE OFF GEARING AT V/STOL HORSEPOWER LEVELS AND EVALUATE IN ACTUAL ENGINE ENVIRONMENT.

## SUMMARY: V/STOL AIRCRAFT RESEARCH FACILITIES

- ASSUMING ONGOING PROGRAMS FOR IMPROVED FACILITIES WILL BE SUCCESSFULLY COMPLETED, GROUND-BASED RESEARCH FACILITIES ARE ADEQUATE FOR ADVANCING V/STOL AIRCRAFT TECHNOLOGY
- SUBSONIC LOW-DISC LOADING V/STOL FLIGHT RESEARCH FACILITIES ARE ADEQUATE
- SUBSONIC HIGH-DISC LOADING V/STOL FLIGHT RESEARCH FACILITIES ARE NEEDED.
- SUPERSONIC V/STOL FLIGHT RESEARCH FACILITIES WILL BE NEEDED.

## GENERAL RECOMMENDATIONS OF NASA V/STOL SUBCOMMITTEE

- NASA PROGRAMS MUST BE INDEPENDENT OF DOD PROGRAMS, AND PROVIDE BROAD TECHNOLOGY BASE FOR FUTURE DECISIONS ON V/STOL OPTIONS
- NASA PROGRAM INADEQUATE IN TIME & SCOPE. ENHANCEMENTS REQUIRED IN AREAS OF:
  - AIRFRAME CONFIGURATIONS
  - PROPULSION/LIFT SYSTEMS
  - AERO/PROPULSION INTERACTIONS
  - CONTROLS
  - ENVIRONMENTAL FACTORS
- FLESH OUT SUBCOMMITTEE PROGRAM OUTLINE TO A TECHNOLOGY ROADMAP
- INTEGRATE MORE FULLY USE OF TECHNICAL TOOLS & FACILITIES
- UTILIZE TECHNOLOGY DEMONSTRATOR AIRCRAFT

V/STOL PROPULSION TECHNOLOGY

LEWIS V/STOL PROPULSION PROGRAM

- INLETS
- NOZZLES
- THRUST MODULATION
- CONTROLS

LEWIS TECHNOLOGY PROGRAMS APPLICABLE TO V/STOL PROPULSION

- ENERGY EFFICIENT ENGINE ($E^3$)
- VARIABLE CYCLE ENGINE (VCE)
- HELICOPTER TRANSMISSION PROGRAM

ADDITIONAL V/STOL TECHNOLOGY NEEDS

- DUCTING AND VALVING
- HIGH COMPRESSOR BLEED
- LIFT ENGINES
- RALS PROPULSION SYSTEM
- EJECTOR LIFT SYSTEM
- LIFT FANS

## RESULTS FROM V/STOL R&D

- DEMONSTRATED FEASIBILITY
- DEMONSTRATED KEY TO SUCCESS
  - PROPULSION
  - LOW-SPEED CONTROL
  - INTEGRATION
- IDENTIFIED PROMISING CONCEPTS AND CONFIGURATIONS
- DEVELOPED TECHNOLOGY TO POINT THAT:
  - SEVERAL CONFIGURATIONS ARE READY FOR PRE-PRODUCTION PROTOTYPING
  - AN OPERATIONAL AIRCRAFT WAS PRODUCED

## ADDTIONAL V/STOL TECHNOLOGY NEEDS

### DUCTING AND VALVING

- EJECTOR LIFT CONCEPT, RALS SYSTEM AND CONTROL JETS ALL REQUIRE THE PIPING OF SIGNIFICANT AIRFLOW QUANTITIES OR AIRFLOW AT HIGH PRESSURES.
- ADDITIONAL TECHNOLOGY NEEDED FOR AERODYNAMICALLY EFFICIENT AND LIGHT-WEIGHT DUCTING AND VALVING

### HIGH COMPRESSOR BLEED

- SOME V/STOL PROPULSION SYSTEM CONCEPTS REQUIRE UP TO 20 OR 25% OF BLEED FROM THE COMPRESSOR.
- TECHNOLOGY BASE NEEDED FOR DESIGN OF EFFICIENT AND ACCEPTABLE STALL MARGIN COMPRESSOR BLEED SYSTEMS.

## ADDITIONAL V/STOL TECHNOLOGY NEEDS

LIFT ENGINES

RALS PROPULSION SYSTEMS (UNIQUE ASPECTS)

EJECTOR LIFT SYSTEM

LIFT FANS

# V/STOL TECHNOLOGY DEVELOPMENTS

TECHNOLOGY AREAS WHICH REQUIRE DEVELOPMENT FOR ADVANCED V/STOL ARE:

- PROPULSION DEVELOPMENT & AIRFRAME INTEGRATION
- FLIGHT CONTROL AT LOW SPEEDS AND VTOL
- STRUCTURES
- AERODYNAMICS (LOW AND HIGH SPEED)

NEEDED DEVELOPMENTS AND OPTIONS:

- LIFT/CRUISE ENGINES AND THRUST VECTORING NOZZLES
- VCE/RALS CONCEPT DATA
- DESIGN METHODS FOR GROUND EFFECTS, REINGESTION, ETC.
- LIFT FAN/LIFT ENGINES WITH HIGH T/W AND COMPATIBLE INSTALLATION
- PROPULSION/AERODYNAMIC CONTROLS INTEGRATION
- LOW SPEED HANDLING QUALITIES METHODS AND DATA
- POWERED LIFT ENHANCEMENT - LOW SPEED & TRANSONIC MANEUVERS
- DYNAMIC LOADS IN ROUGH FIELD OPERATION
- LIGHTWEIGHT STRUCTURE FOR ACOUSTIC/THERMAL ENVIRONMENT
- IFR DISPLAYS & AUXILIARY EQUIPMENT FOR NIGHT/ADVERSE WEATHER V/STOL OPERATIONS

VOUGHT

# V/STOL TECHNOLOGY – IN HAND

- ENGINE THRUST TO WEIGHT
- LIGHTWEIGHT STRUCTURE
- V/STOL CONTROL POWER REQUIREMENTS

# V/STOL Technology Requirements

| | STOL | VTOL |
|---|---|---|
| **Propulsion** | | |
| Lift engine thrust to weight | | ● |
| Cruise engine thrust to weight | | ● |
| Thrust vectoring | | ● |
| Mechanical power transmission | | ● |
| Ground-effect interactions | | ● |
| **Structure** | | |
| Advanced composites | | ● |
| High-temperature materials (nozzle impingement, vectoring, and reaction controls) | | ● |
| **Flight control** | | |
| Reaction control systems | | ● |
| Integrated propulsion and control | ● | ● |
| **Aerospace ground equipment** | | |
| Austere site equipment | ● | ● |
| Onboard diagnostics | ● | ● |

# Advanced Aircraft Technologies

| PROJECT TITLE | V/STOL | CTOL |
|---|---|---|
| COMPOSITE STRUCTURES (CSAA) | ✓ | ✓ |
| NAVTOLAND | ✓ | |
| ADVANCED A/C ELECTRIC SYSTEM (AAES) | ✓ | ✓ |
| ADVANCED RADAR | ✓ | ✓ |
| LIGHT WEIGHT HYDRAULIC (LT WT HYD) | ✓ | ✓ |
| AVIOPTICS | ✓ | ✓ |
| DIGITAL FLY-BY-WIRE (DFCS) | ✓ | ✓ |
| MODULAR AVIONICS PACKAGE (MAP) | ✓ | ✓ |
| INTEGRATED INERTIAL SENSOR ASSEMBLY (IISA) | ✓ | ✓ |
| LIGHT WEIGHT ENVIRONMENTAL CONTROL (ECS) | ✓ | ✓ |
| MULTI-SENSOR PROCESSOR (MSP) | ✓ | ✓ |
| TACTICAL INFO EXCHANGE (TIES) | ✓ | ✓ |
| INFO HANDLING SYSTEM (IHS) | ✓ | ✓ |
| MULTI-ENGINE DYNAMIC CONTROL (DYN CONTROL) | ✓ | ✓ |
| DRIVE SYSTEM COMPONENTS | ✓ | |
| FAN CHARACTERISTICS | ✓ | |
| ENGINE TEST FACILITIES MOD | ✓ | |
| ADVANCED INTEGRATED DISPLAY SYSTEM (AIDS) | ✓ | ✓ |

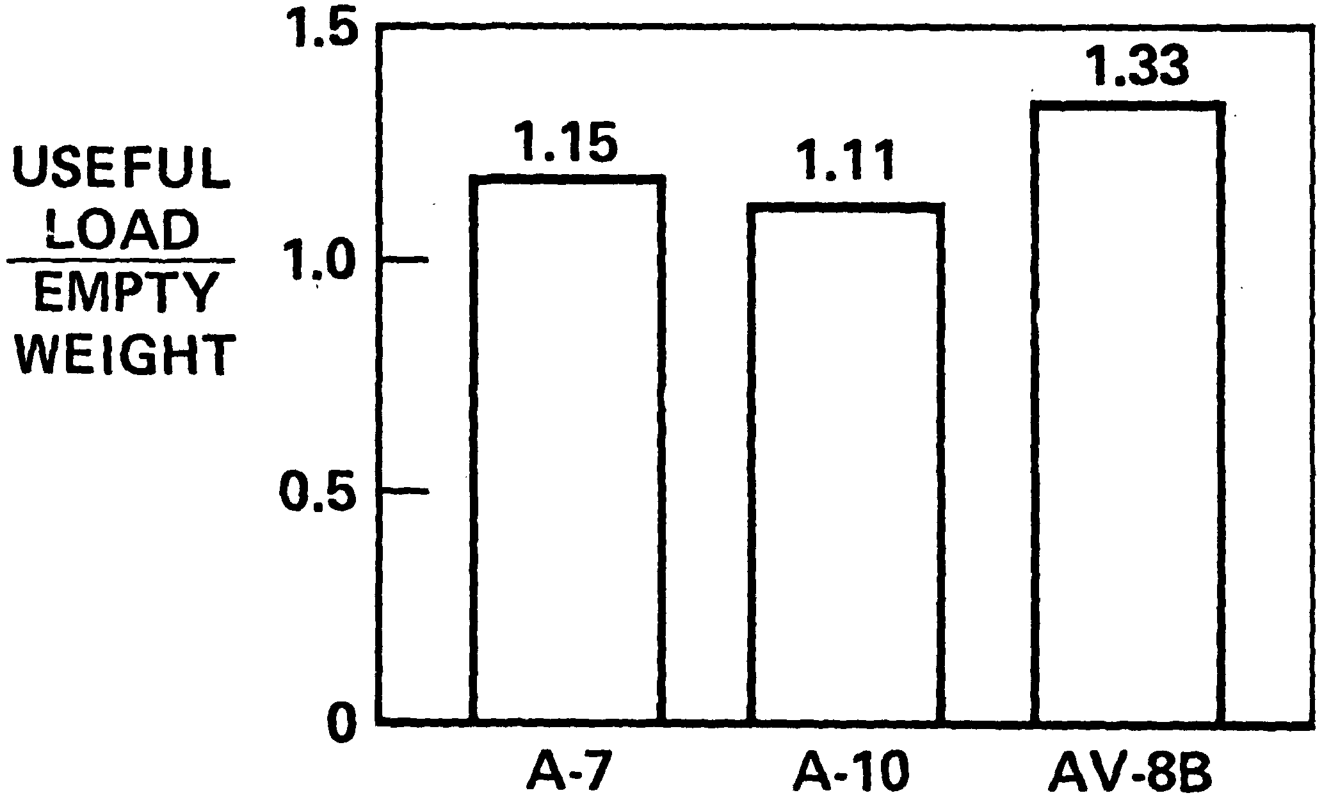
# REQUIRED SUPPORTING SUBSYSTEM TECHNOLOGY ADVANCES

| | BENEFITS | | | |
|---|---|---|---|---|
| Technology | $\Delta$ Wt | $\Delta$ Perf | $\Delta$ R&M | $\Delta$ Vol |
| Low Speed Air Data Systems | | X | | |
| Strapdown (Shared) Intertial Sensors | | X | X | |
| Global Positioning System | | X | | |
| JTIDS | | X | X | |
| Advanced Displays | X | X | X | X |
| Integrated Racks | X | X | X | X |
| Fiber Optics | X | X | | |
| HI Voltage DC Power | X | X | X | X |
| Secondary Power System | X | X | | |
| Environmental Control Sys | X | X | X | X |
| On-board Oxygen System | | X | | |
| Lightweight Hydraulic System | X | X | | X |
| TIES | X | X | X | X |
| Digital Flt. Control System | | X | X | X |

# SUBSYSTEMS TECHNOLOGY ASSESSMENT

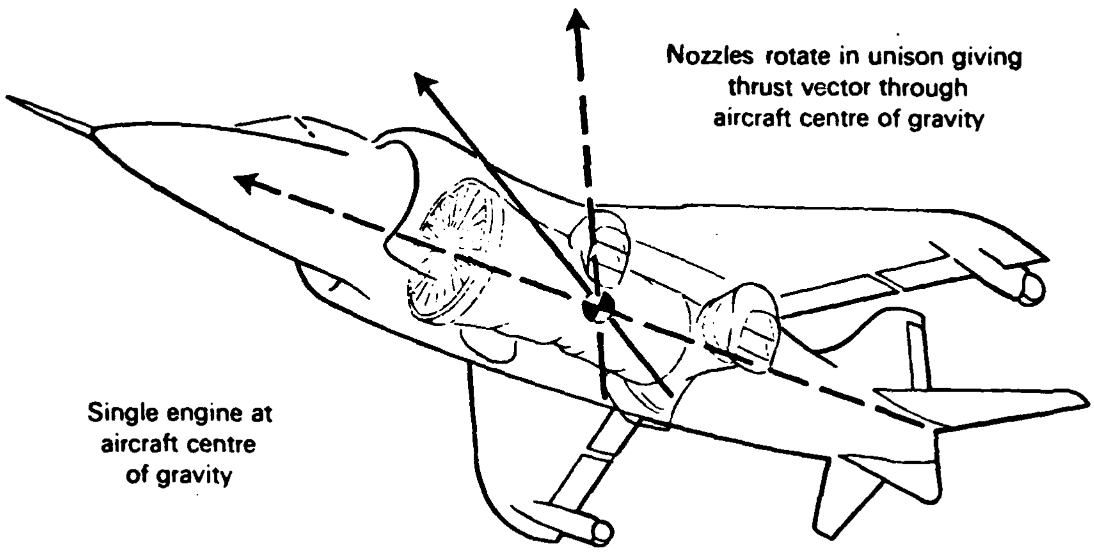
| Subsystem | Pacing Technologies | Deficiencies | |
|---|---|---|---|
| | | Operational | Design Requirements Definition |
| Flight Control | Digital Flight control system (DFCS)<br>NAVTOLAND | Landing Control | Integration with propulsion controls<br>• fly-by-light<br>• transitional control |
| Electrical | Advanced Aircraft Electrical System (AAES)<br>270 VDC generators<br>multiplexing<br>solid state electronic logic | Reliability & Maintainability | |
| Hydraulics | Lt. Wt. Hydraulics System (LHS)<br>8000 PSI System | Reliability & Maintainability | |
| Environmental Control | Modular Avionics Packaging (MAP)<br>Lt. Wt. Environmental Control System | Reliability & Maintainability | Integration with avionics packaging |

# VECTORED THRUST PROVIDES EFFICIENT USEFUL LOAD




| | A-7 | A-10 | AV-8B |
|---|---|---|---|
| EMPTY WEIGHT (LB) | 19,500 | 22,500 | 12,750 |
| GROUND ROLL (FT) | 8,100 | 4,350 | 1,200 |

## THE VECTORED-THRUST PRINCIPLE




## ADVANTAGES OF VECTORED-THRUST

- Only one extra cockpit lever required – to control nozzle thrust vector angle
- Manual control of jet-borne flight stability and transition to wingborne flight
- Vectoring in forward flight (VIFF) enhances combat effectiveness
- Single large engine reduces cost and performance degradation
- Vectoring nozzles reduce duration and hence adverse effects of exhaust energy near ground

# ENGINE THRUST RATING OF AV-8A

## STANDARD DAY SEA LEVEL STATIC

| RATING | | PEGASUS 11 AVERAGE (LB) |
|---|---|---|
| SHORT LIFT WET | (15 SEC) | 21,500 |
| NORMAL LIFT WET | (90 SEC) | 20,950 |
| SHORT LIFT DRY | (15 SEC) | 20,500 |
| NORMAL LIFT DRY | (2.5 MIN) | 19,500 |
| COMBAT | (2.5 MIN) | – |
| MAXIMUM THRUST | (15 MIN) | 16,750 |
| INTERMEDIATE | (30 MIN) | – |
| MAXIMUM CONTINUOUS | | 13,500 |
| AV-8A O.W.E. | (UNLIMITED) | 12,200 |

CURRENT STUDY MAXIMUM RATING

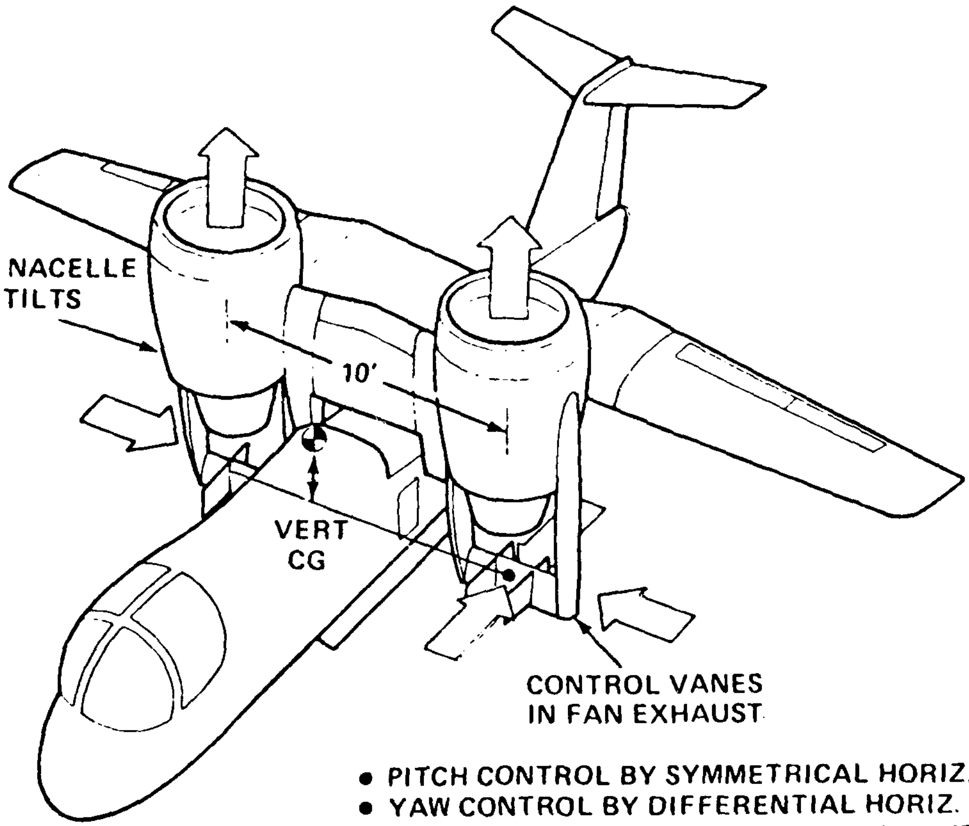
## AV-8A SKI JUMP
## PHASE I
## COMPLETED

- MEDIUM GIRDER BRIDGE SKI JUMP INSTALLED AT NATC PATUXENT RIVER, MD
- 55 AV-8A/TAV-8A LAUNCHES 26 MARCH TO 23 APRIL 1979 AT NATC
- 12 DEGREE RAMP, MAX X-WIND 10 KTS, MIN THRUST: WEIGHT = .85
- TAKE-OFF COMPARISONS

| | | SKI JUMP | SHOREBASED | SHIPBOARD |
|---|---|---|---|---|
| WOD | (KTS) | 0 | 0 | 0 |
| GROSS WT | (#) | 19,300 | 19,300 | 19,300 |
| GROUND RUN | (FT) | 197 | 652 | 450 |
| LIFT OFF | (KTS) | 56 | 86 | 110 |
| NOZZLES | | 45 | 65 | 55 |

- CONFIRMED BENEFITS
  - INCREASED PERFORMANCE
  - IMPROVED HANDLING-REDUCED WORKLOAD
  - IMPROVED SAFETY-HANDLING + TERRAIN CLEARANCE

# VERTICAL FLIGHT CONTROL
# (TYPE D DESIGN 698-409)



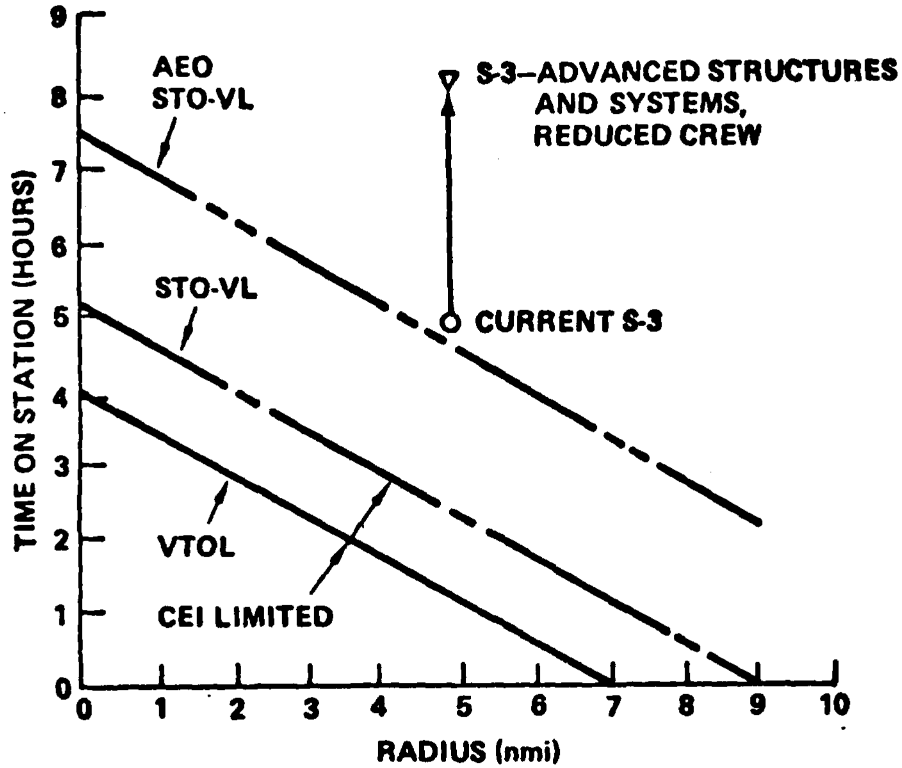

- PITCH CONTROL BY SYMMETRICAL HORIZ. VANE DEFLECTION
- YAW CONTROL BY DIFFERENTIAL HORIZ. VANE DEFLECTION
- ROLL CONTROL BY DIFFERENTIAL THRUST & VERTICAL VANE DEFLECTION
- TRANSLATIONAL TRIM BY NACELLE TILT & SYMMETRICAL HORIZ. VANE
- HEIGHT CONTROL BY COLLECTIVE THRUST

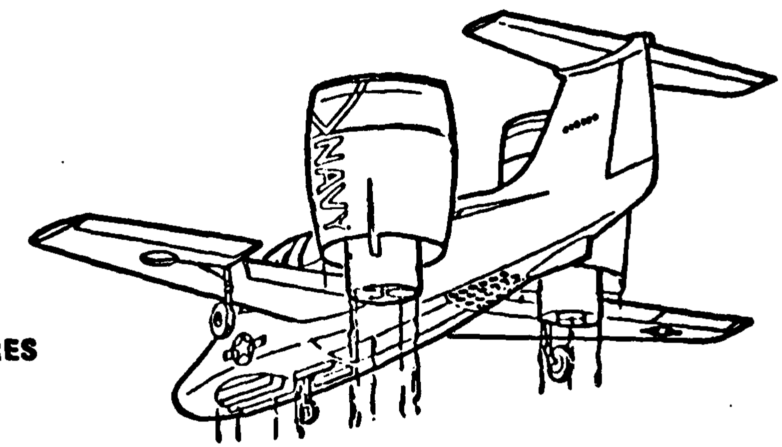


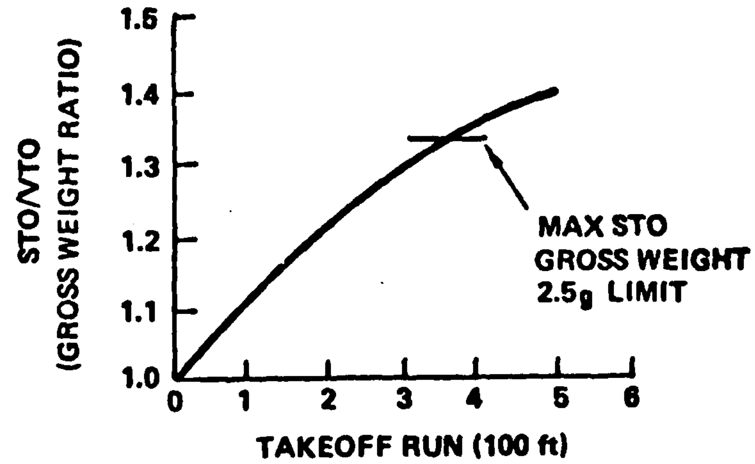
0018-004W

# Lift Fan Characteristics

- **CEI–LIMITED**
  - VTO gross weight 40,800 lb
  - STO gross weight 43,200 lb
- **AEO**
  - STO gross weight 53,700 lb

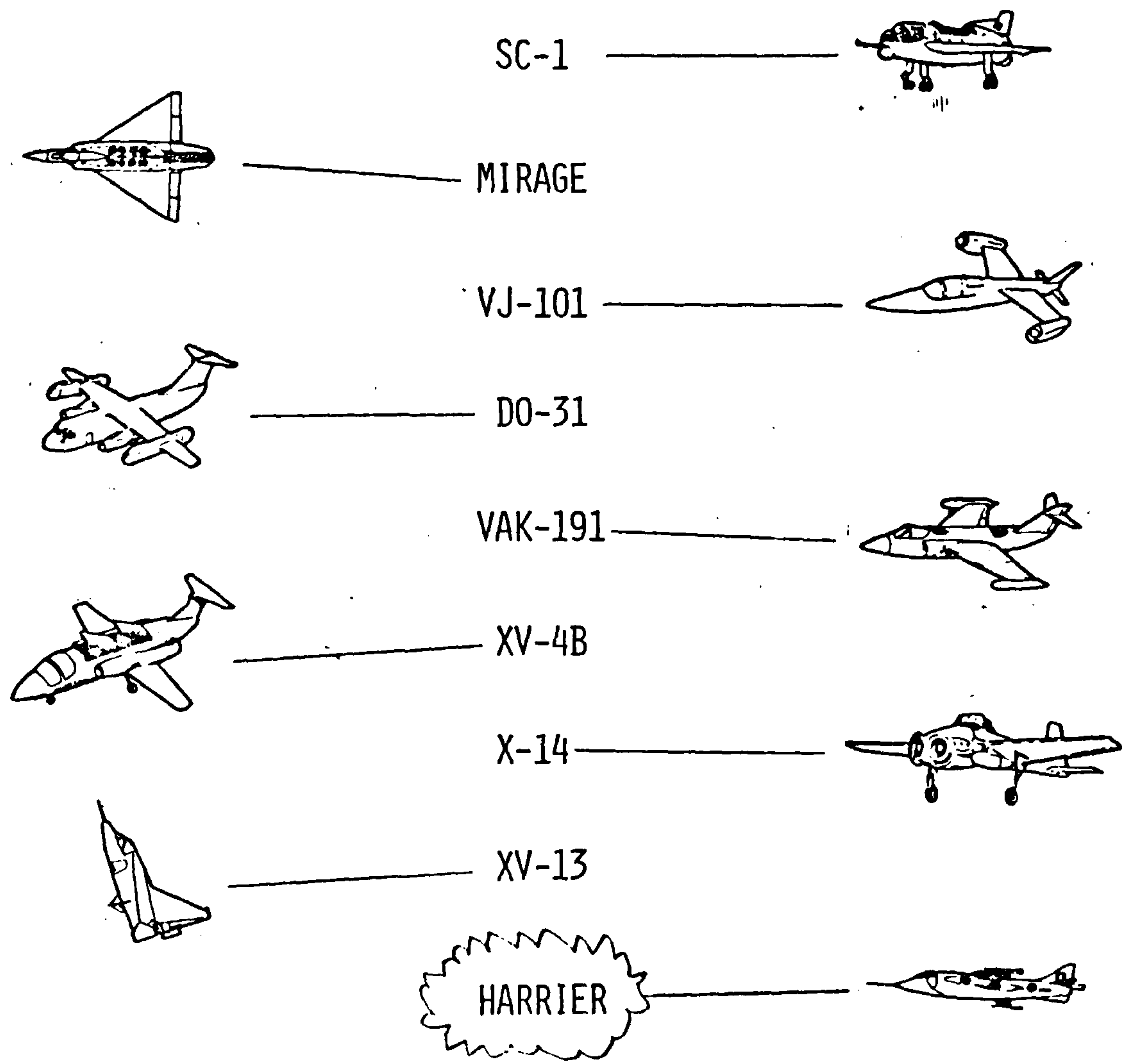


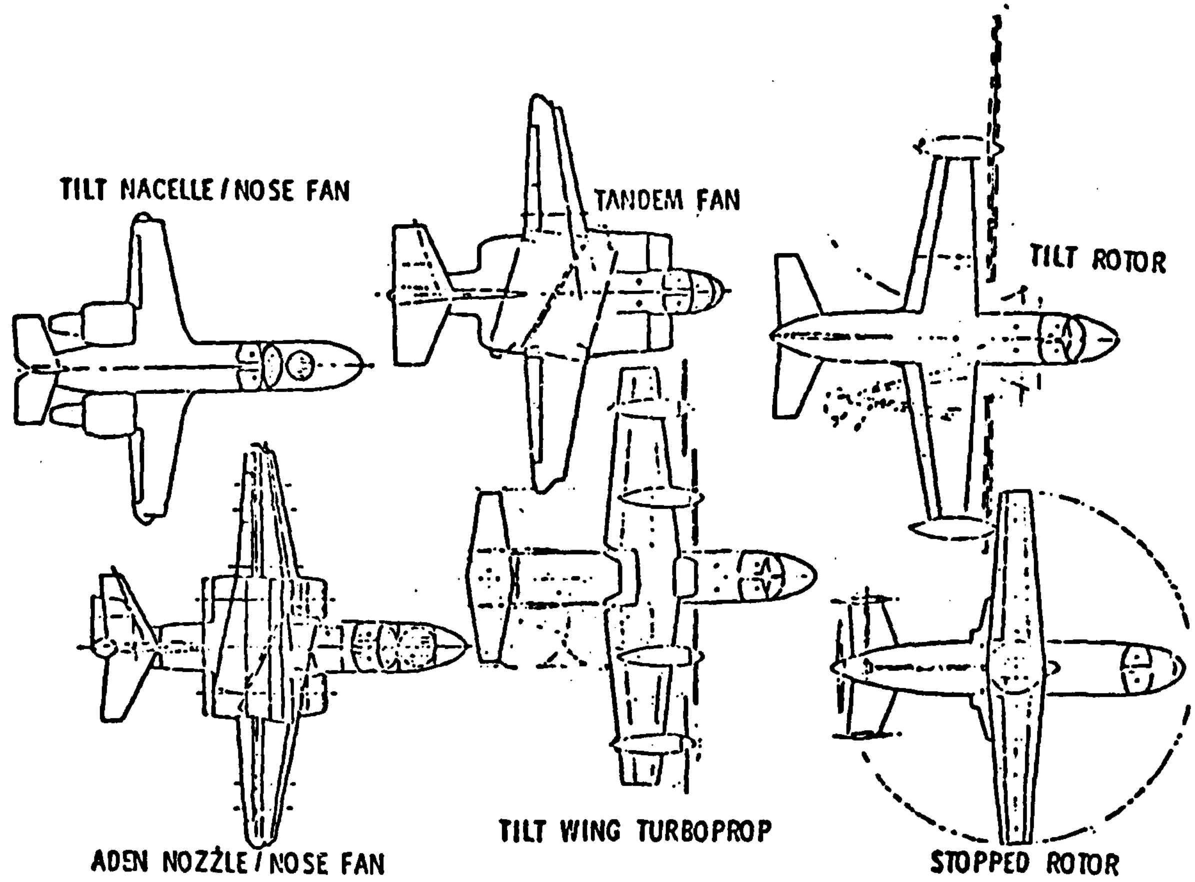



# V/STOL EXPERIMENTAL AIRCRAFT

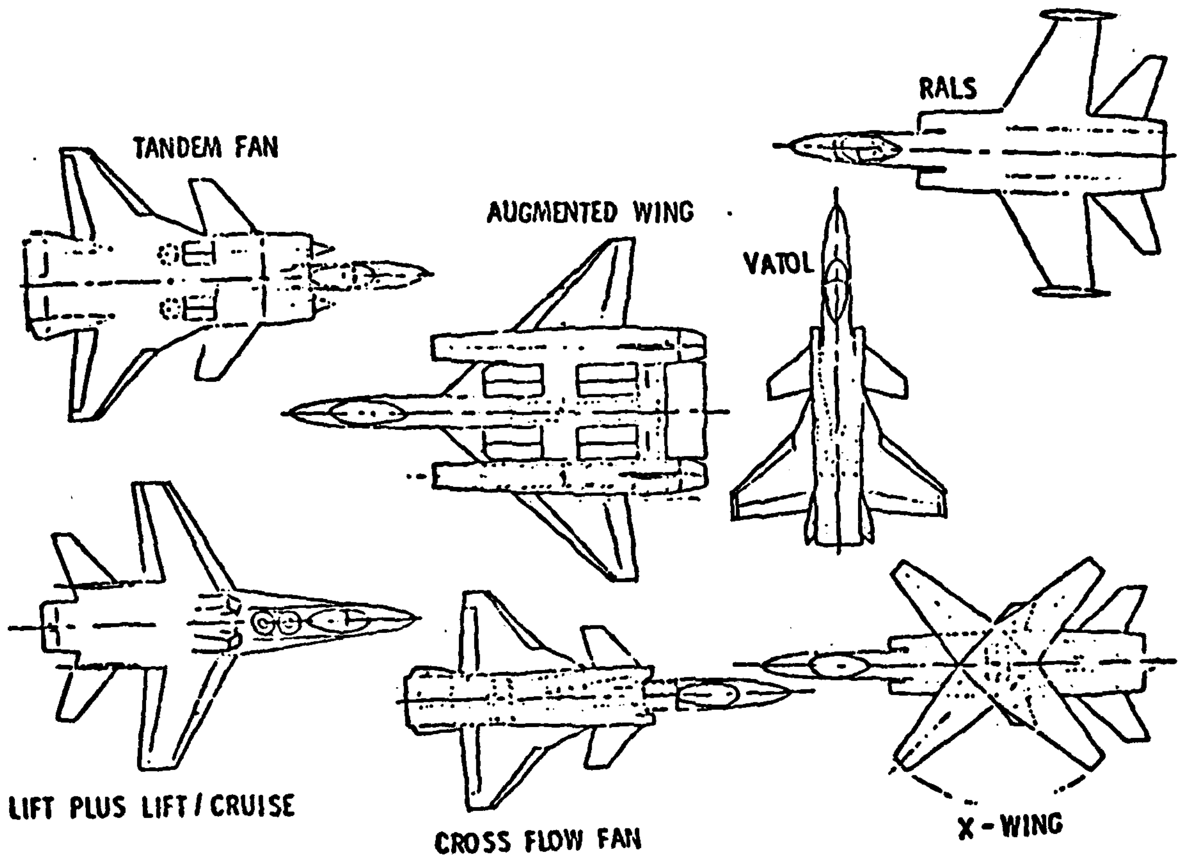
DIRECT JET LIFT



# CANDIDATE SUBSONIC CONCEPTS

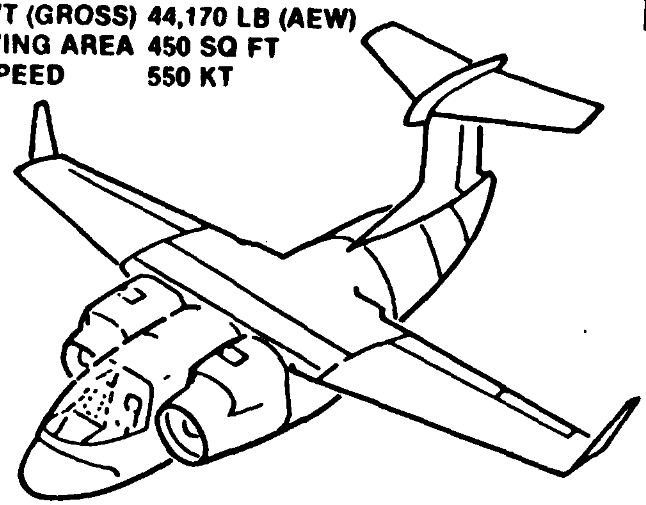


# CANDIDATE SUPERSONIC CONCEPTS



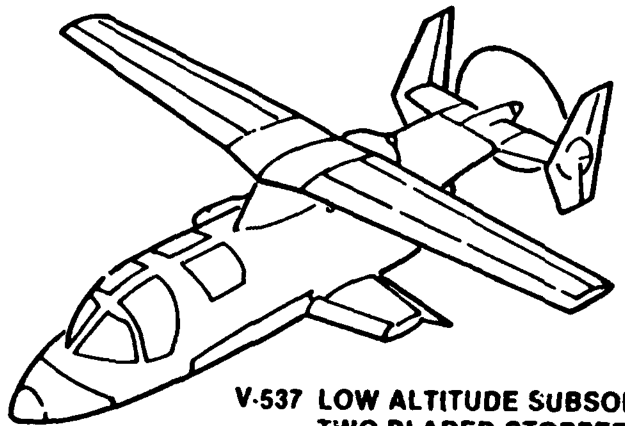
# VOUGHT
# V/STOL CONFIGURATIONS FOR NAVAL OPERATIONS

WT (EMPTY) 30,900 LB
WT (GROSS) 44,170 LB (AEW)
WING AREA 450 SQ FT
SPEED 550 KT



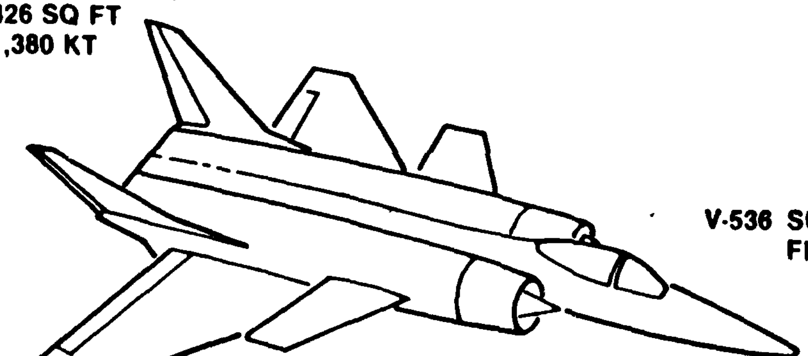
V-530 HIGH ALTITUDE
SUBSONIC TANDEM FAN
OPERATIONAL SUPPORT

WT (EMPTY) 25,400 LB
WT (GROSS) 37,000 LB TROOP CARRIER
WING AREA 350 SQ FT
SPEED 400 KT



V-537 LOW ALTITUDE SUBSONIC
TWO-BLADED STOPPED ROTOR
ASSAULT/RESUPPLY

WT (EMPTY) 28,900 LB
WT (GROSS) 48,300 LB (DLI)
WING AREA 426 SQ FT
SPEED 1,380 KT



V-536 SUPERSONIC (SERIES FLOW) TANDEM FAN
FIGHTER/ATTACK

# AV-8B

## IMPORTANCE TO FUTURE OF V/STOL DEVELOPMENT

*TECHNOLOGICALLY*

- LARGE SCALE COMPOSITE STRUCTURE
- IMPROVED AERODYNAMICS
- IMPROVED ENGINE PERFORMANCE

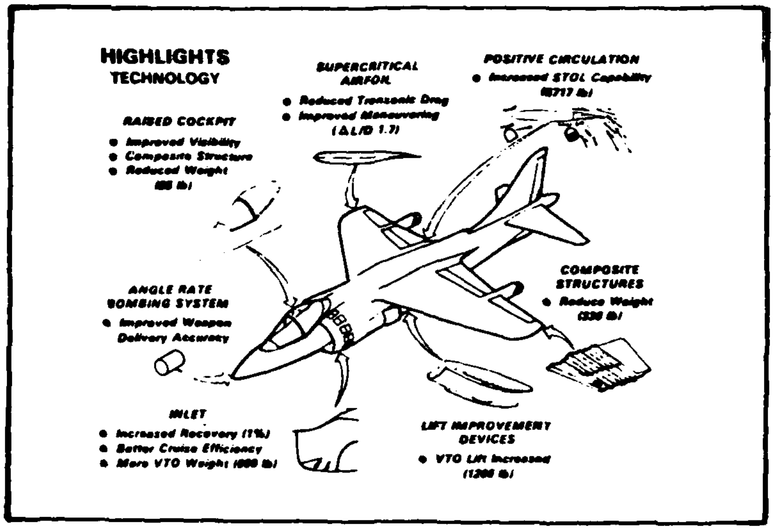
*OPERATIONALLY*

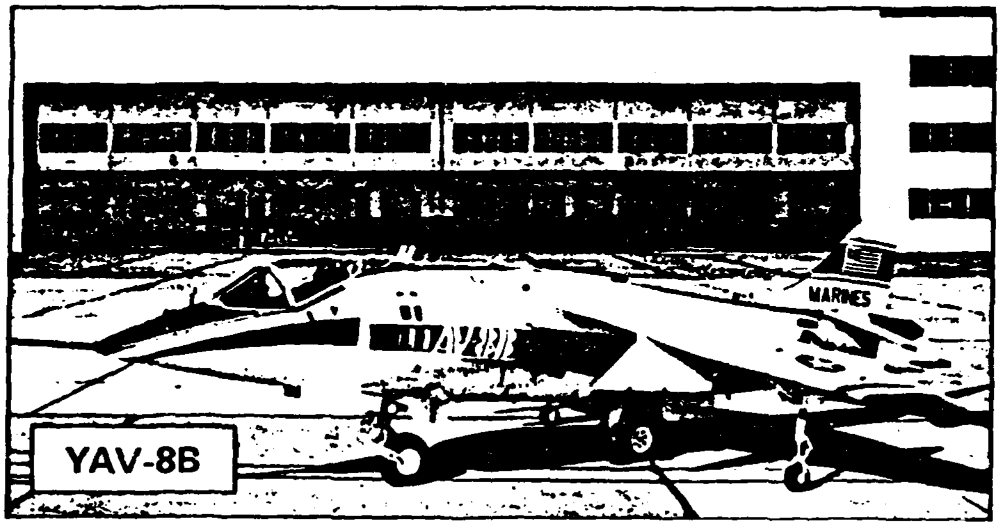
- PROVIDES MEANINGFUL MILITARY CAPABILITY NOW!
- DEMONSTRATE/VALIDATE OTHER V/STOL OPERATIONAL CAPABILITIES

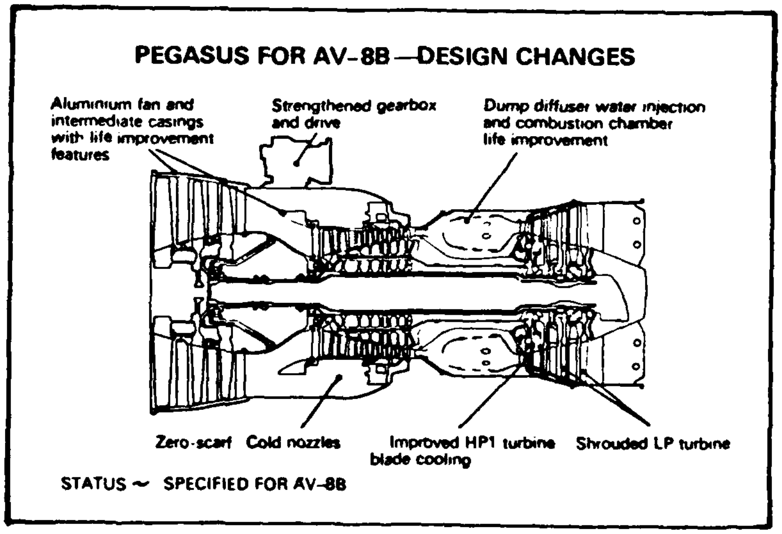
# YAV-8B FLIGHT DEMONSTRATION GUARANTEES

| | GUARANTEE | ACTUAL DEMONSTRATED |
|---|---|---|
| • O.W.E. | 12,550 LB | 12,388 LB |
| • $W_{VTO}$ | 18,860 LB | 19,972 LB* |
| • $W_{STO}$ (1,000 FT) | 27,950 LB | 28,084 LB* (588 FT) |
| • MAX SPECIFIC RANGE (CAS MISSION) | 0.137 NM/LB | |
| • MAX SPECIFIC RANGE (CLEAN CONFIGURATION) | 0.224 NM/LB | |

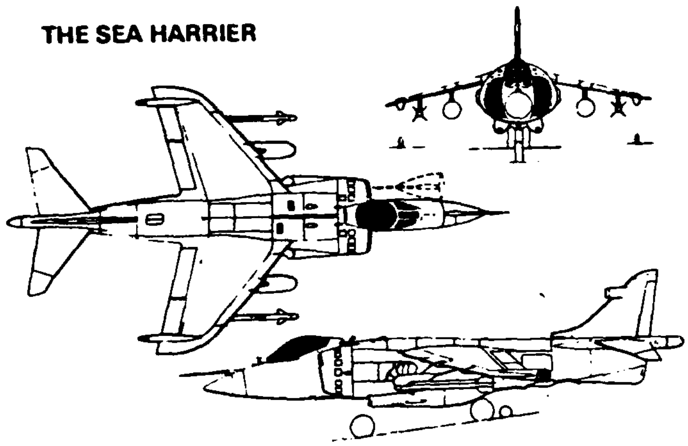
*UNCORRECTED


HIGHLIGHTS
TECHNOLOGY
SUPERCRITICAL AIRFOIL
• Reduced Transonic Drag
• Improved Maneuvering
(ΔL/D 1.7)
POSITIVE CIRCULATION
• Increased STOL Capability
RAISED COCKPIT
• Improved Visibility
• Composite Structure
• Reduced Weight
COMPOSITE STRUCTURES
• Reduce Weight
ANGLE RATE BOMBING SYSTEM
• Improved Weapon Delivery Accuracy
INLET
• Increased Recovery (1%)
• Better Cruise Efficiency
• More VTO Weight
LIFT IMPROVEMENT DEVICES
• VTO Lift Increased

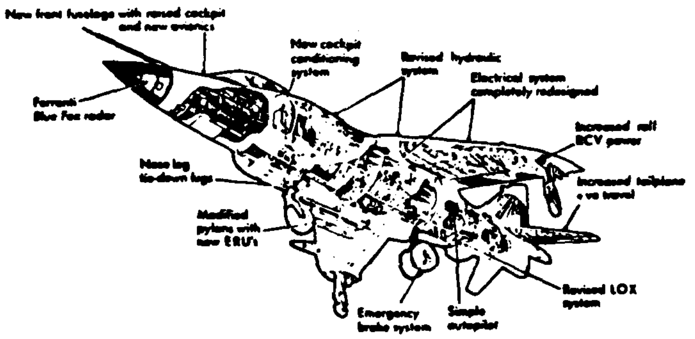

YAV-8B
MARINES


PEGASUS FOR AV-8B—DESIGN CHANGES
Aluminium fan and intermediate casings with life improvement features
Strengthened gearbox and drive
Dump diffuser water injection and combustion chamber life improvement
Zero-scarf
Cold nozzles
Improved HP1 turbine blade cooling
Shrouded LP turbine
STATUS ~ SPECIFIED FOR AV-8B

## THE SEA HARRIER



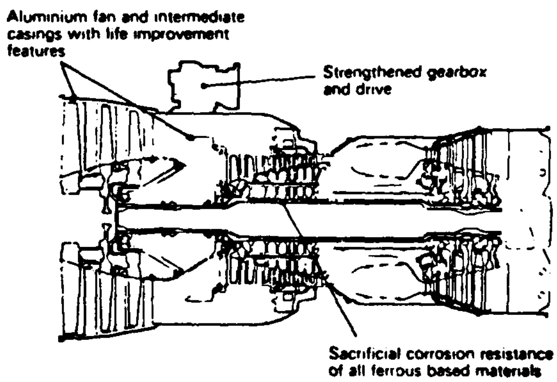
## AIRCRAFT CHANGES FROM GR Mk 3 TO SEA HARRIER




7 Magnesium components eliminated in airframe
2 Major magnesium components eliminated in engine

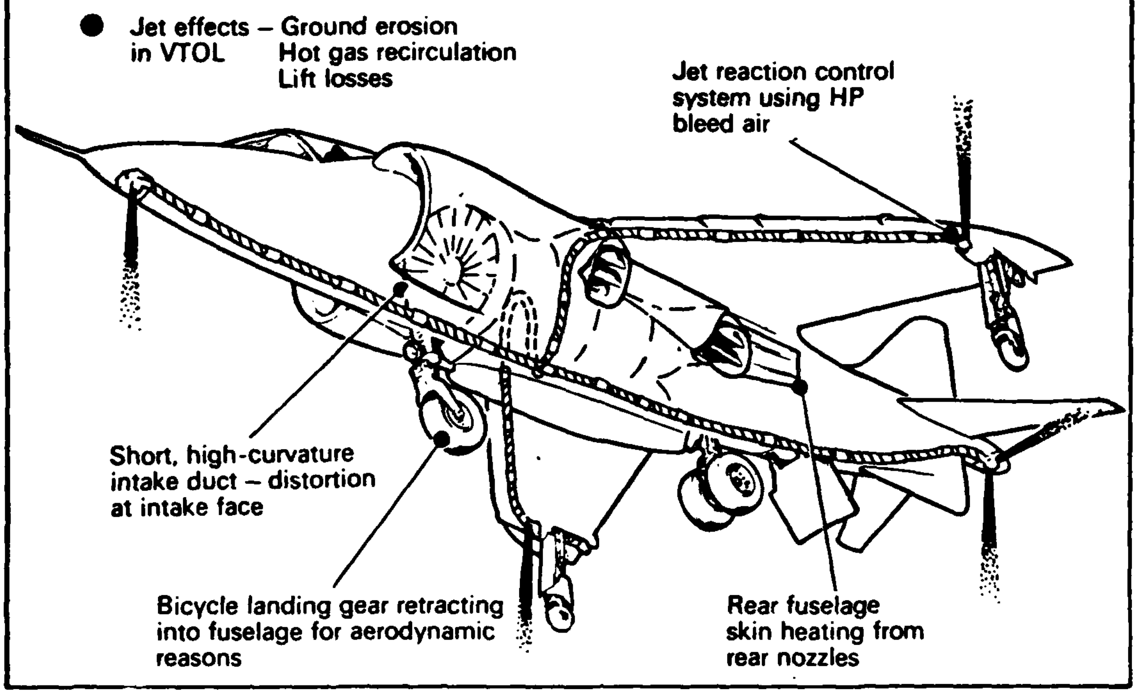
Latest MBA rocket ejection seat (Type 10)
Provision for AAGW and ASGW

## PEGASUS FOR SEA HARRIER—DESIGN CHANGES

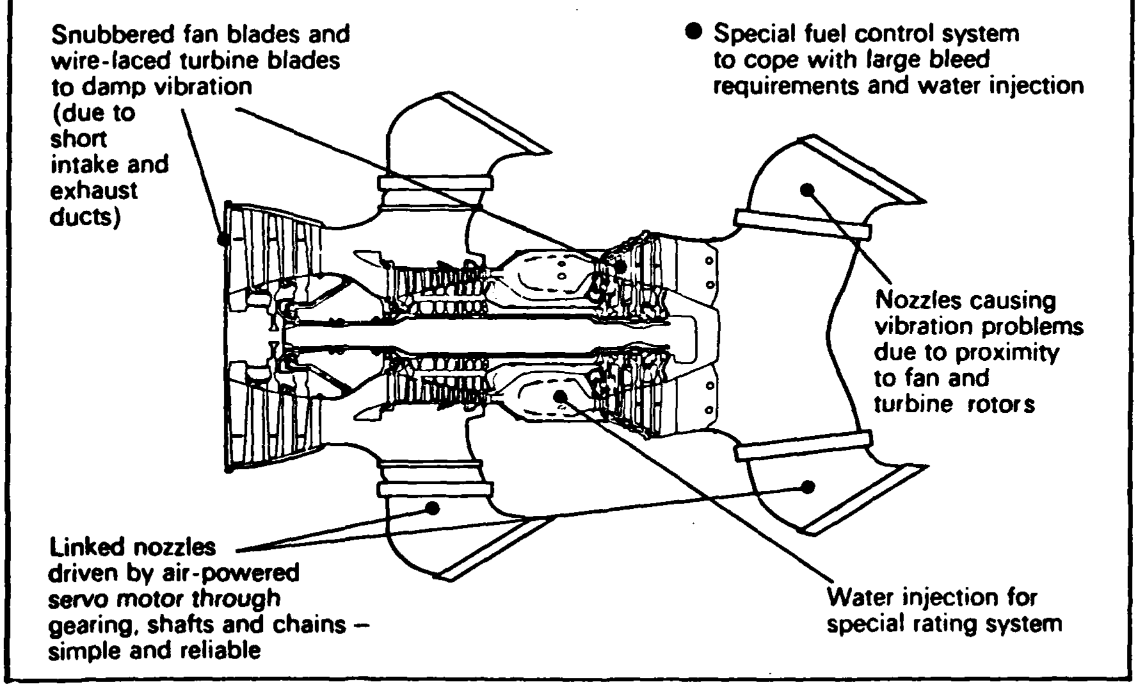



STATUS ~ IN PRODUCTION

## AIRFRAME CONSIDERATIONS

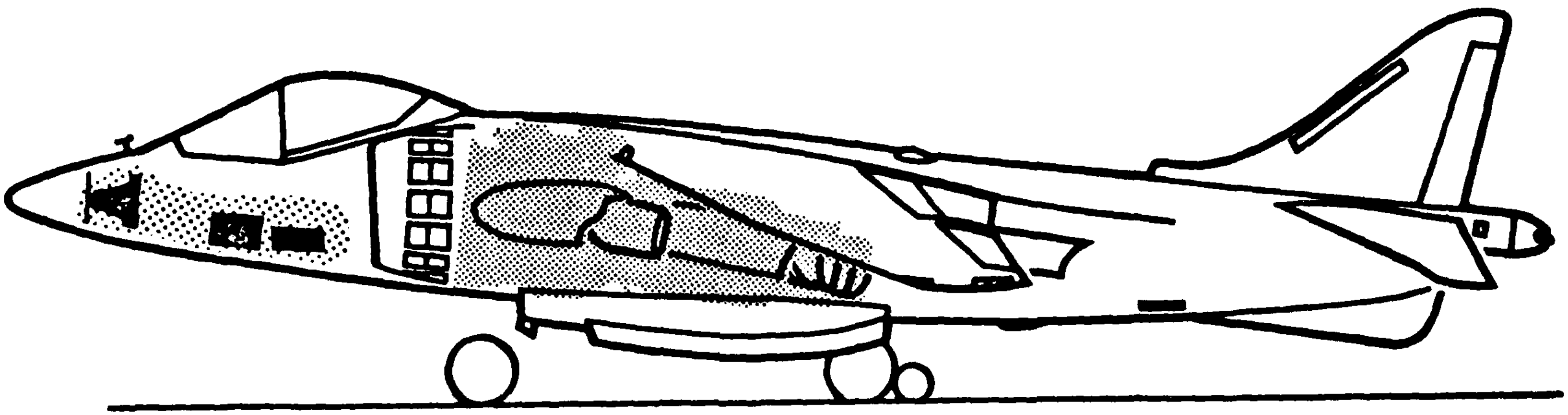



## ENGINE CONSIDERATIONS



# AV-8B +

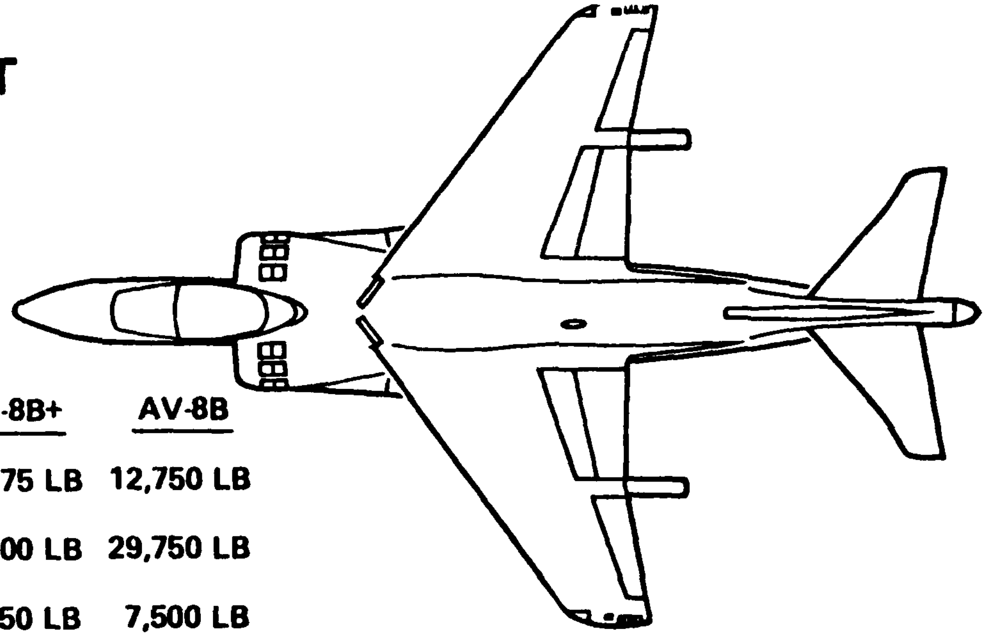
## SAME AS USMC AV-8B



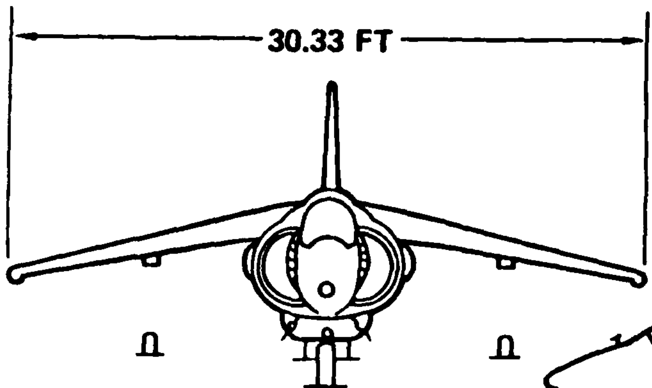
***PLUS***

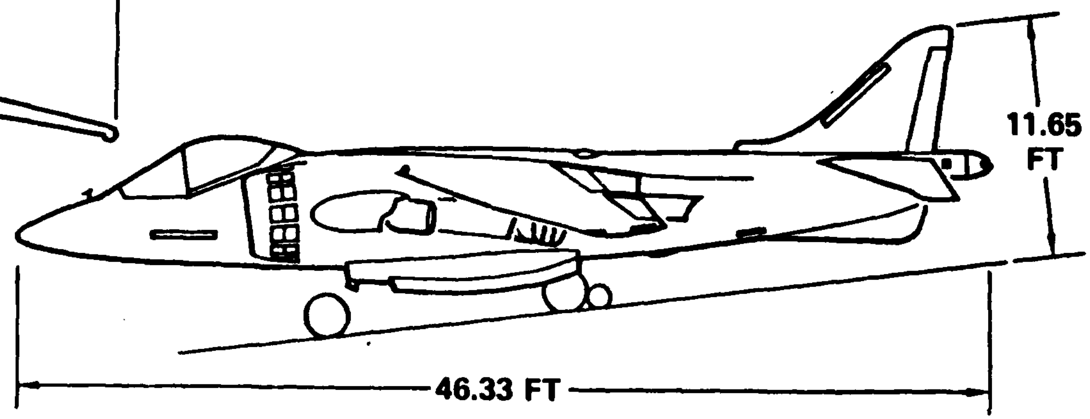
- RADAR, AUTOPILOT AND NAVY AVIONICS SUITE
- MODIFIED PEGASUS ENGINE
- INCREASED INTERNAL FUEL
- NAVY WEAPONS AND 25 mm GUN

# AV-8B+ AIRCRAFT



| | AV-8B+ | AV-8B |
|---|---|---|
| OPERATING WEIGHT EMPTY | 13,475 LB | 12,750 LB |
| MAXIMUM DESIGN GW | 31,000 LB | 29,750 LB |
| INTERNAL FUEL | 7,850 LB | 7,500 LB |
| ENGINE THRUST | 22,600 LB | 21,180 LB |




33-24

# AV-8B+ AVIONIC SUITE

- RADAR (APG-65 BASELINE)
- AUTOPILOT
- MISSION COMPUTER (AN/AYK-14)
- HEAD UP DISPLAY
- MULTIPURPOSE DISPLAY
- VHF-UHF RADIO (AN/ARC-182)
- INERTIAL NAVIGATION (ASN-130)
- TACAN (ARN-118)
- ALL-WEATHER LANDING SYSTEM (ARA-63)
- STORES MANAGEMENT SET
- DEFENSIVE ELECTRONIC COUNTERMEASURES POD
- RADAR WARNING RECEIVER (ALR-67)
- FLARE CHAFF DISPENSER (ALE-39)

# MODIFIED HARRIER RESEARCH AIRCRAFT

- OBJECTIVE

  ESTABLISH A DATA BASE IN FLIGHT DYNAMICS TO ASSURE SATISFACTORY PILOT RATINGS FOR V/STOL AND STOL AIRCRAFT IN TAKEOFF, LANDING, AND TRANSITION

  – CURRENT CRITERIA BASED ON ANALYTICAL AND PILOTED SIMULATION STUDIES

  – NEED INVESTIGATIONS IN FLIGHT USING LAND-BASED AND SHIPBOARD TASKS

- APPROACH

  – MODIFY A TWO-PLACED HARRIER

  – CONDUCT FLIGHT RESEARCH IN FLIGHT CONTROL SYSTEMS, PILOT'S DISPLAYS, AND GUIDANCE SYSTEMS

# FLIGHT EXPERIMENTS USING MODIFIED HARRIER RESEARCH AIRCRAFT

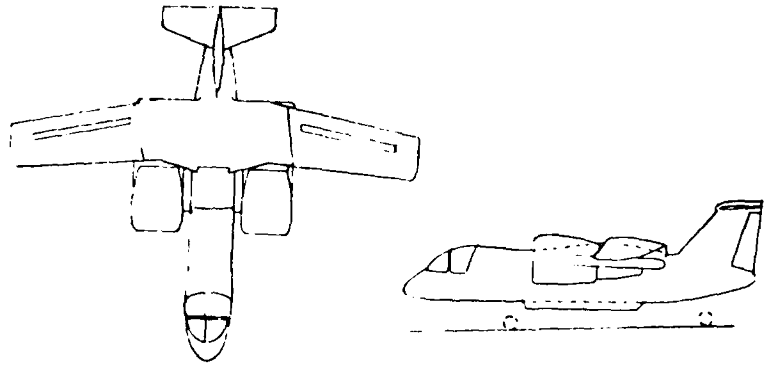
- OPERATIONS
  - TRANSITION, APPROACH, LANDING, TAKEOFF
  - SIMULATED IMC CONDITIONS
  - LANDING ABOARD SHIP AND IN CONFINED AREAS
- FLIGHT CONTROL SYSTEM AND DISPLAY INVESTIGATIONS
  - RATE DAMPING
  - ATTITUDE STABILIZATION
  - VELOCITY COMMAND
  - CONTROLLER
  - HEAD-UP DISPLAY
  - DIRECTOR/SITUATION
- NAVIGATION AND GUIDANCE SYSTEMS INVESTIGATIONS
  - APPROACH PROFILES
  - MICRO WAVE LANDING SYSTEM
  - DISPLAYS

# FLEET AIR ENHANCEMENT BY TWO POSSIBLE SUBSONIC TURBOFAN V/STOLs

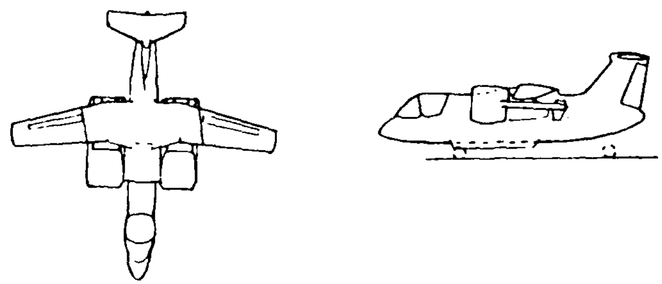
- TYPE D DESTROYER/CRUISER DESIGN
  - ENTIRELY NEW CAPABILITY
    - ▲ OTH (SURFACE, AIR)
    - ▲ SLAT (HARPOON, TOMAHAWK)
    - ▲ MISSILEER
    - ▲ JAMMER
  - MUST FIT ALL HANGARS
  - MUTUAL ENHANCEMENT WITH MPA
  - COMPLIMENTARY TO LAMPS III
- TYPE A V/STOL SHIP/CARRIER DESIGN
  - SHIP SIMPLIFICATION (CAT & ARR GEAR)
  - RELIEF OF DECK CYCLE CONSTRAINTS
  - STOL OPS FOR INCREASED PAYLOAD

# DESIGN 698
# TURBOFAN V/STOL VERSIONS

- DES 698-412, TYPE A: ~ 44,000 LB



- DES 698-409, TYPE D: ~ 20,000 LB





GRUMMAN

# TYPE D V/STOL DESIGN 698-409 CHARACTERISTICS

| | TF-34 (30% UPGRADE) | NEW TECH ENG |
|---|---|---|
| • TOGW-LB VTO | 20,332 | 21,265 |
| • ÇREW | 2 | 2 |
| • SPEEDS, $M_{CRUISE}$ | 0.59 | 0.60 |
| $M_{MAX}$ | 0.80 | 0.80 |
| • CEILING, FT | 50,000 | 50,000 |
| • RATE OF CLIMB, FT/MIN (MIN TO 30,000 FT) | 14,850 (2.7) | 21,840 (1.6) |
| • PROPULSION | | |
| • FUEL (FRACTION) | STD DAY: 4140 (.21)<br>TROP DAY: 3980 (.20) (WET) | 5400(.25)* MAX INT<br>5400(.25)* FUEL |
| • MISSION LOAD, VTOL TROP DAY | 1 CREW + 2735 LB<br>2 CREW + 2276 LB | |
| • LOITER TIME, HR @ 100 N MI RADIUS | TROP DAY/STD DAY | TROP DAY |
| VTOL | 1.9 (WET)/2.1 | 3.6 |
| STOL | 2.8 (WET)/ – | 4.3** |

* ENG FLAT RATED
**2-150 GAL. DROP TANKS





0563-009

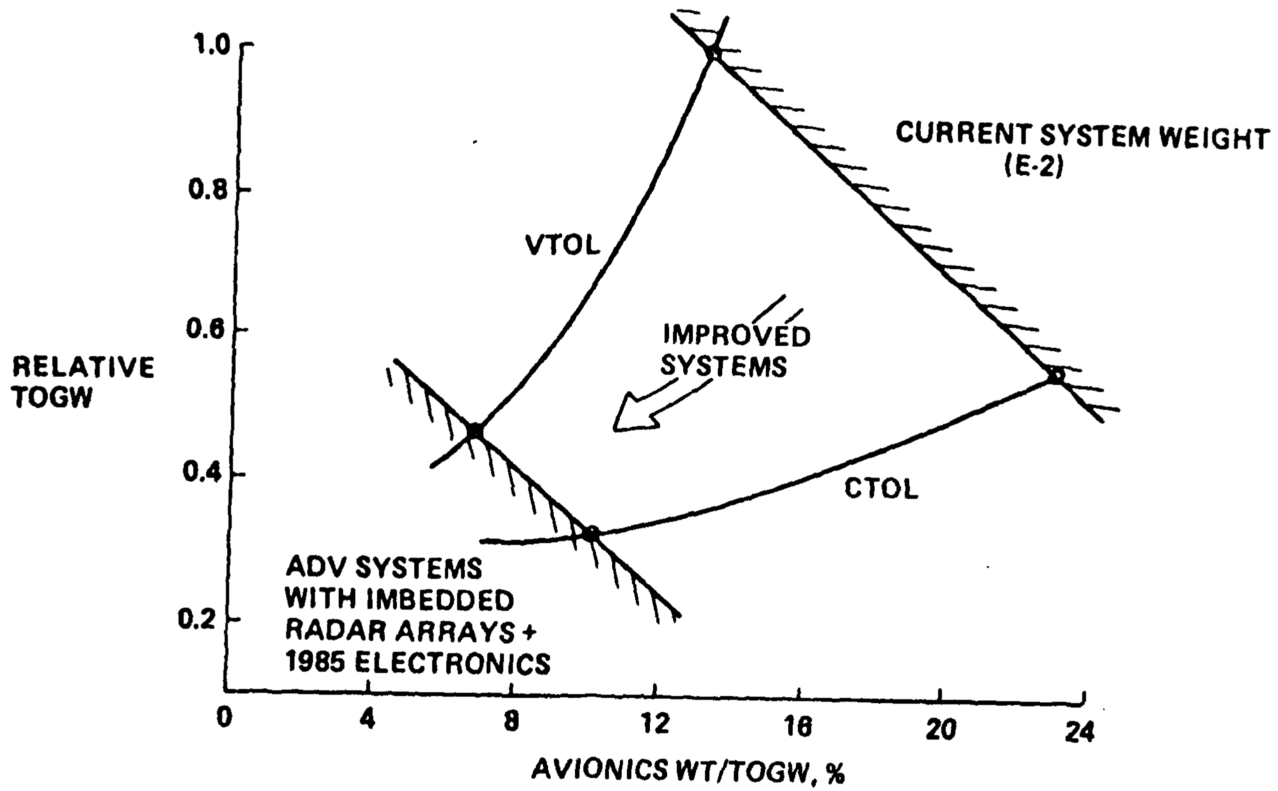
Supporting Data

Avionics/Weapons

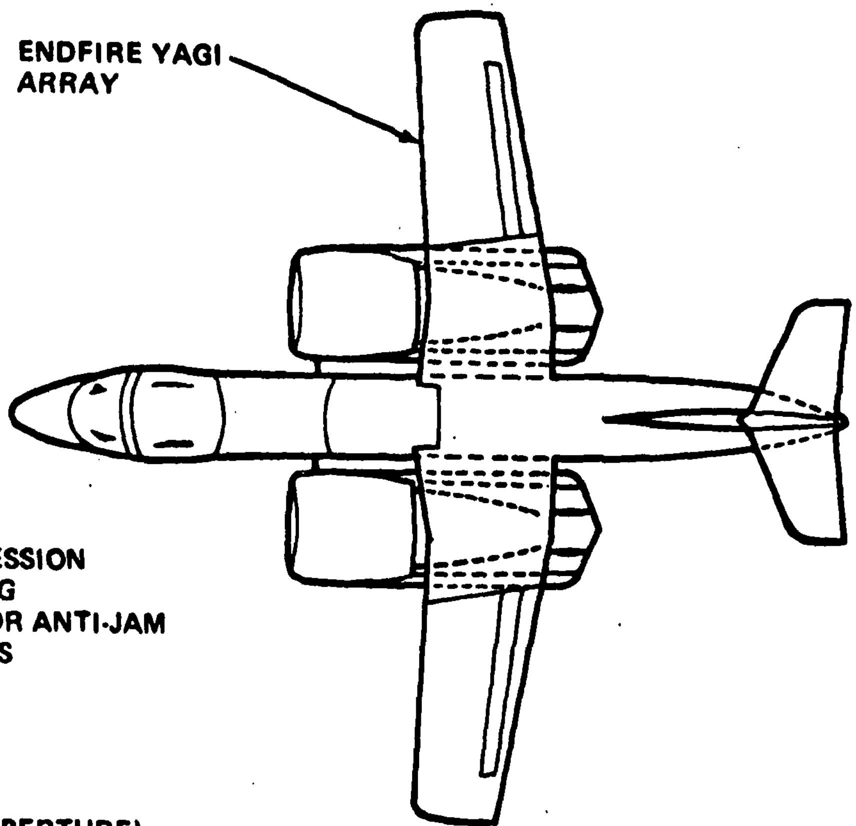
# ADVANCED AVIONICS MAKE VTOL PRACTICAL

## SUBSONIC SURVEILLANCE AIRCRAFT

- EQUIVALENT SYSTEM CAPABILITIES
- SEA CONTROL MISSION



# LIGHTWEIGHT CONFORMAL RADAR IS ADAPTABLE TO SMALL FIXED-WING AIRCRAFT

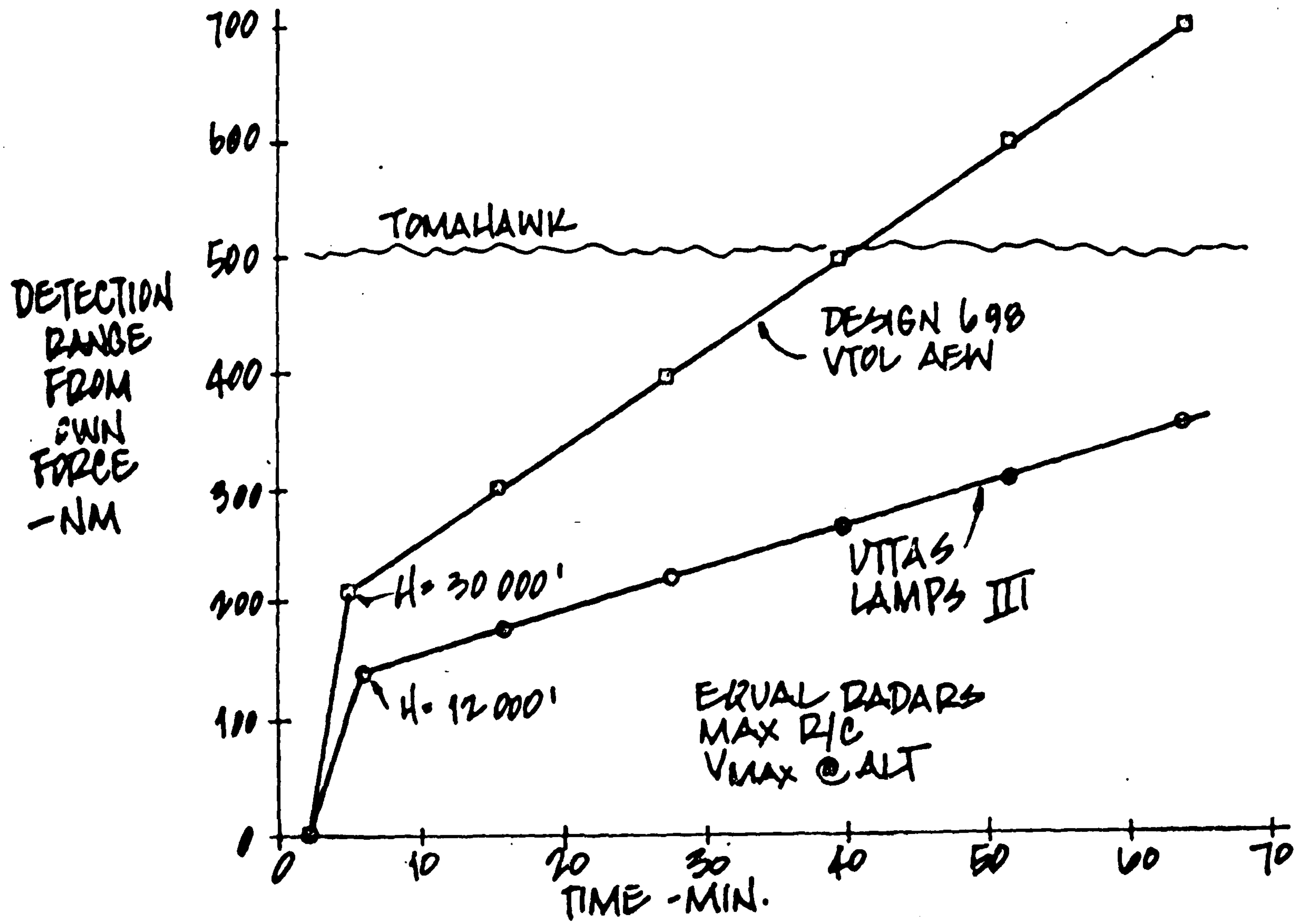



- ANTENNAS
  - FLUSH MOUNTED
  - ELECTRONICALLY SCANNED
- RADAR SYSTEM FEATURES
  - 100% SOLID STATE MODULAR DESIGN
  - UHF FOR LOW SYS WEIGHT & COST
  - LOW PEAK POWER WITH PULSE COMPRESSION
  - NEW-TECHNOLOGY SIGNAL PROCESSING
  - ADAPTIVE ANT. PATTERN CONTROL FOR ANTI-JAM
  - OPTIMIZED AIR & SURF. SEARCH MODES
  - EST. WEIGHT APPROX ~ 625 LB
- NEW OPERATING CAPABILITIES
  - BEAM POWER MANAGEMENT
  - EXTENDED RANGE DETECTION ZONES
  - HI-RESOLUTION "ZOOM" (SYNTHETIC APERTURE)



2512-030W

# REACTIVE SURFACE SURVEILLANCE / SLAT ROLE



## CONCEPTUAL SLAT

| | |
|---|---|
| LAUNCH MODE: | VERTICAL |
| SPEED: | MACH 3.5 - 4.0 |
| WARHEAD: | CONVENTIONAL 200 LBS |
| GUIDANCE: | 1. COMMAND INERTIAL GUIDANCE |
| | 2. DIRECT COMMAND GUIDANCE |
| | 3. PRELAUNCH DESIGNATION |
| TERMINAL PHASE: | 1. HOME ON JAM |
| | 2. ACTIVE RADAR |
| | 3. INERTIAL |

Supporting Data

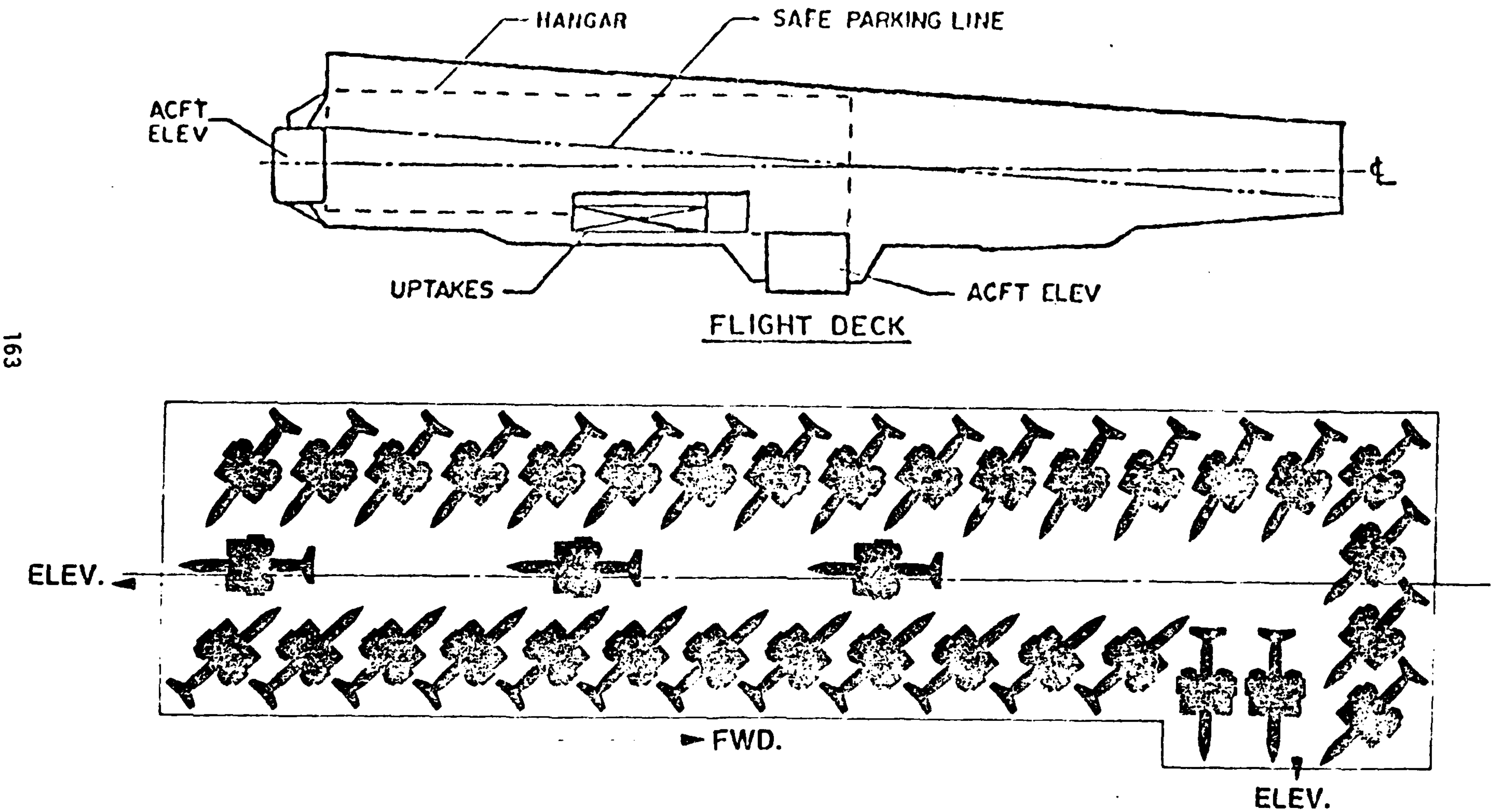
Platforms

# CANDIDATE V/STOL SHIPS

| | CV | CVV | VSS | VES |
|---|---|---|---|---|
| DISPLACEMENT (THOUSAND TONS) | 80-90 | 60 | 30 | 5-15 |
| FLIGHT DECK LENGTH (FEET) | 1000 | 900 | 700 | 300-500 |
| AIRCRAFT CAPACITY (TYPICAL) | 82-106 (CTOL) | 50-64 (CTOL) | 20 (V/STOL) | 6-12 (VTOL) |
| CATAPULTS | 4 | 2 | 0 | 0 |
| NUMBER IN INVENTORY | 12/11 | 0 | 0 | 0 |
| PROCUREMENT COST (FY 79 DOLLARS) | $1.8-2.4B | $1.4B | $500-700M | |

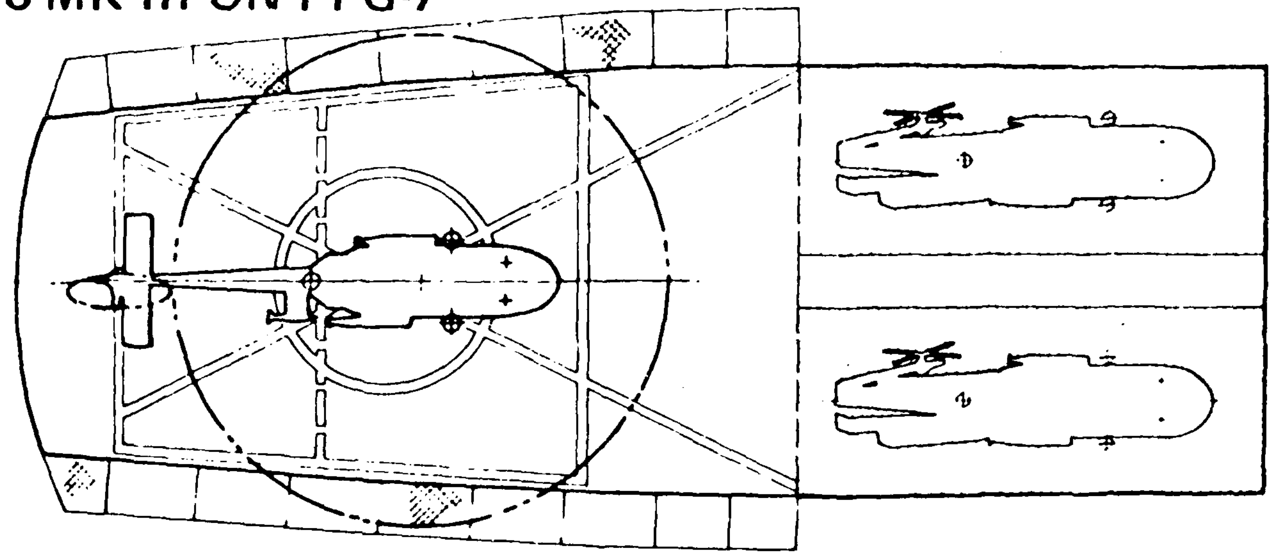
| TYPE AIRCRAFT | ALTERNATE PLATFORMS | APPROXIMATE NO. OF AIRCRAFT |
| --- | --- | --- |
| STOAL (SHORT TAKEOFF/ ARRESTED LANDING) STOVL, V/STOL | STOAL CV - LENGTH 800', BEAM 135', DISPLACEMENT 40,000 TONS, MINIMUM PROTECTION, FLIGHT AND HANGAR DECK, CONTAINERSHIP TYPE HULL | 26-30 |
| STOVL, V/STOL | VSS-D - LENGTH 700', BEAM 178', DISPLACEMENT 29,000 TONS MONOHULL, FLIGHT AND HANGAR DECK, MAGAZINE PROTECTION | 20-27 |
| STOVL, V/STOL | DDV-2 - LENGTH 684', BEAM 116', DISPLACEMENT 18,000 TONS, MONOHULL FLIGHT AND HANGAR DECK SKI JUMP MAGAZINE PROTECTION | 10 |
| STOVL, V/STOL | SWATH-6 - LENGTH 500', BEAM 126', DISPLACEMENT 18,000 TONS, (SMALL WATERBORNE TWIN HULL) HANGAR STARBOARD SIDE OF FLIGHT DECK MINIMUM PROTECTION | 6 |
| V/STOL | DDV-1D - LENGTH 564', BEAM 68', DISPLACEMENT 11,000 TONS, MONOHULL MINIMUM PROTECTION, FLIGHT DECK AFT | 5 |

# DESIGN 698-409 ON VSS-D

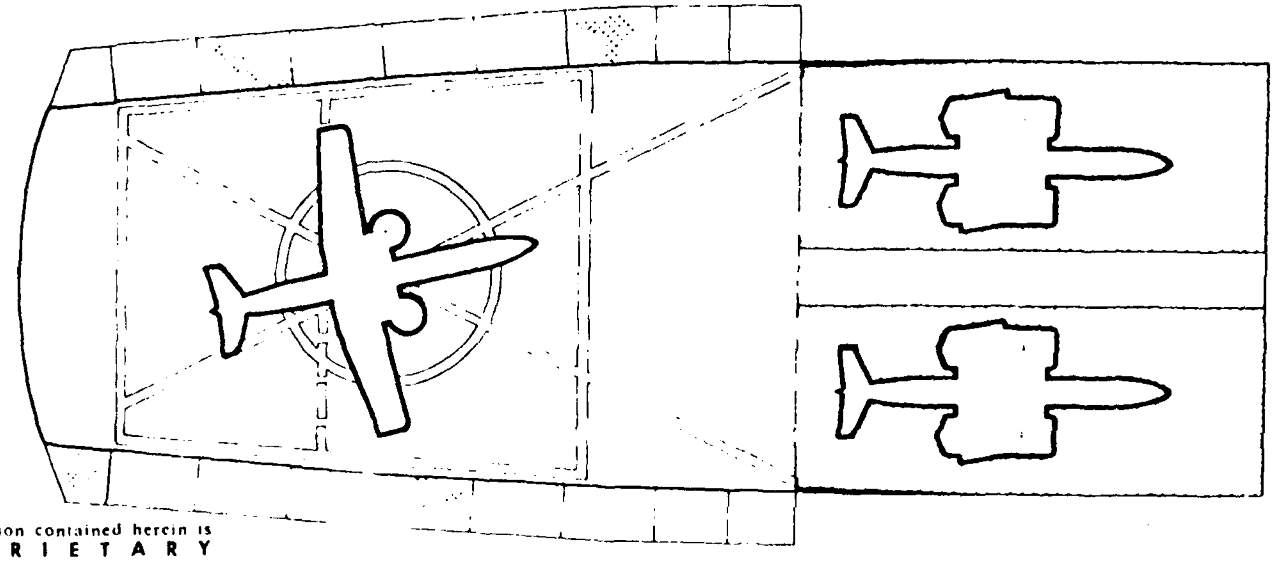



APPROXIMATE HANGAR OUTLINE FROM DATA AVAILABLE 3/8/79

LAMPS MK III ON FFG-7



TYPE D DESIGN 698-409 ON FFG-7

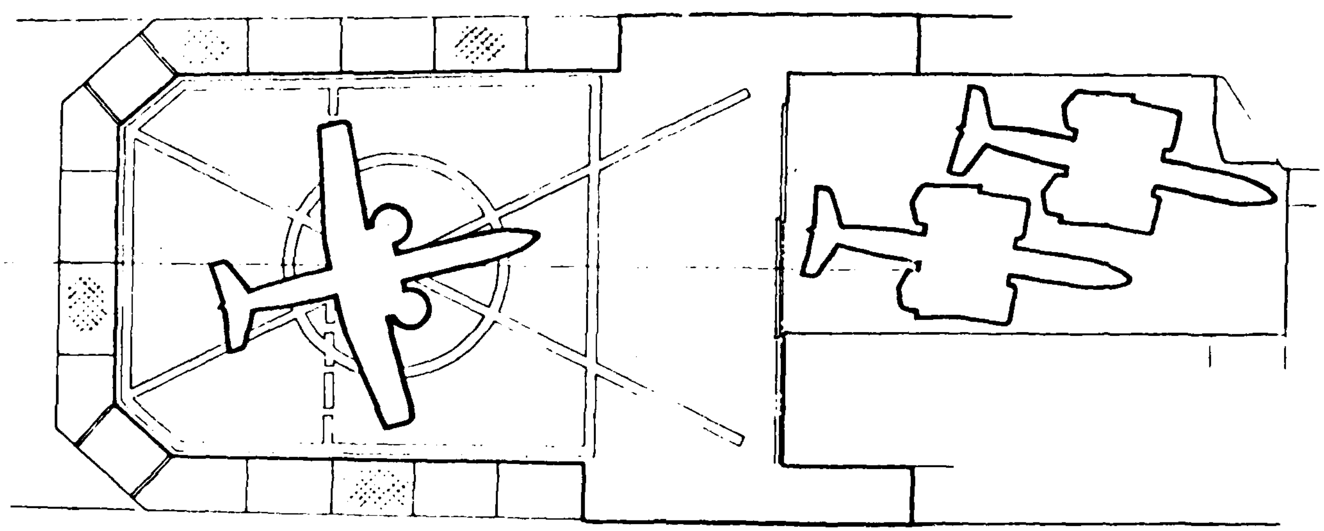


The information contained herein is
P R O P R I E T A R Y
to Grumman Aerospace Corporation

3012-020W

GRUMMAN

# TYPE D DESIGN 698-409 ON DD-963

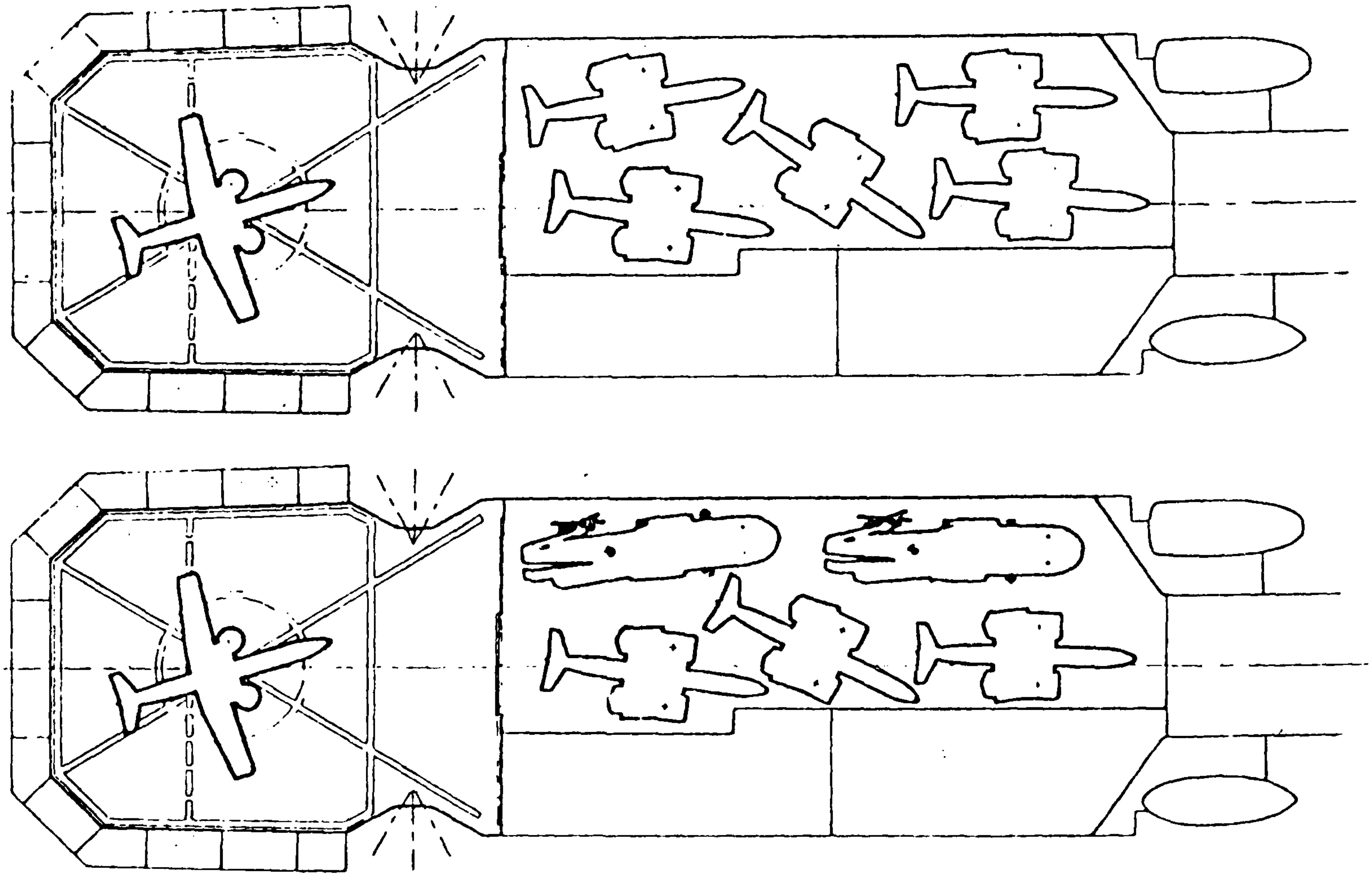




3012 021W

GRUMMAN

# TYPE D DESIGN 698-409 ON DDH

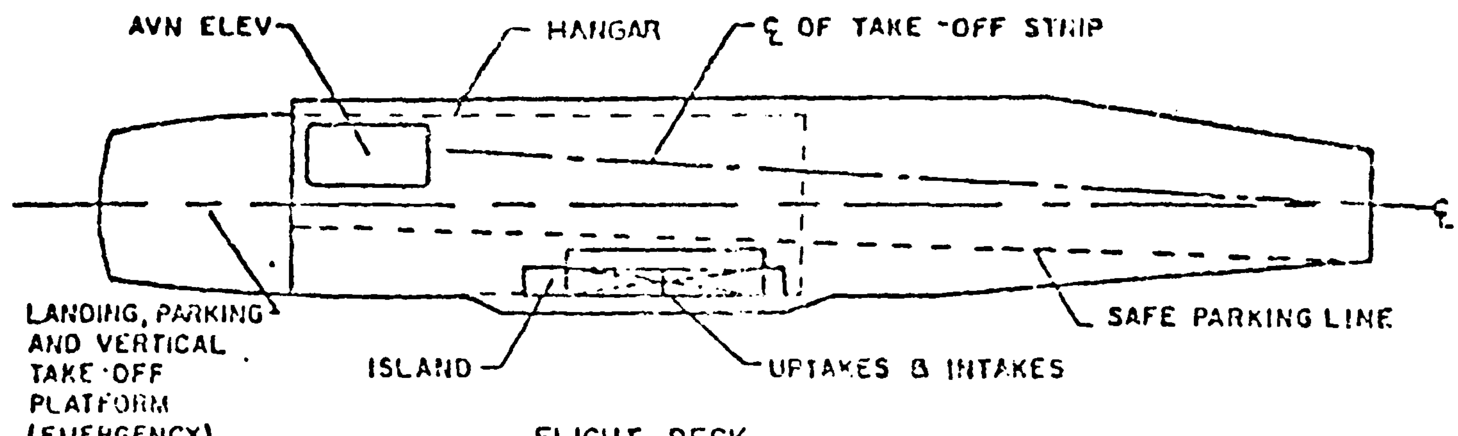


The information contained herein is
P R O P R I E T A R Y
to Grumman A-rospace Corporation

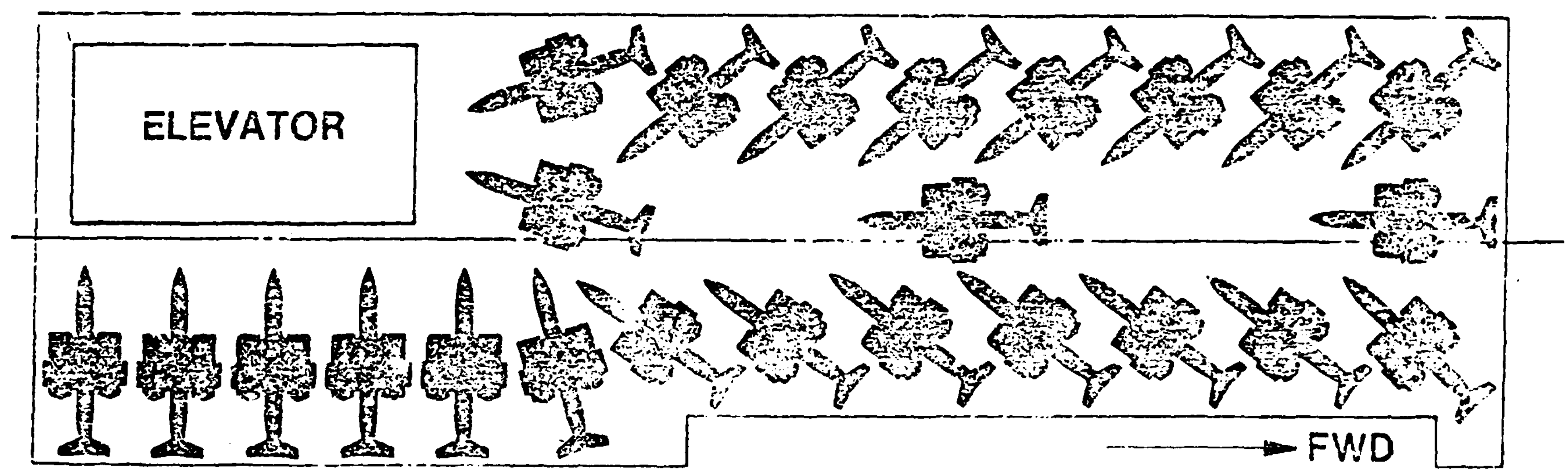
3012-012W

GRUMMAN

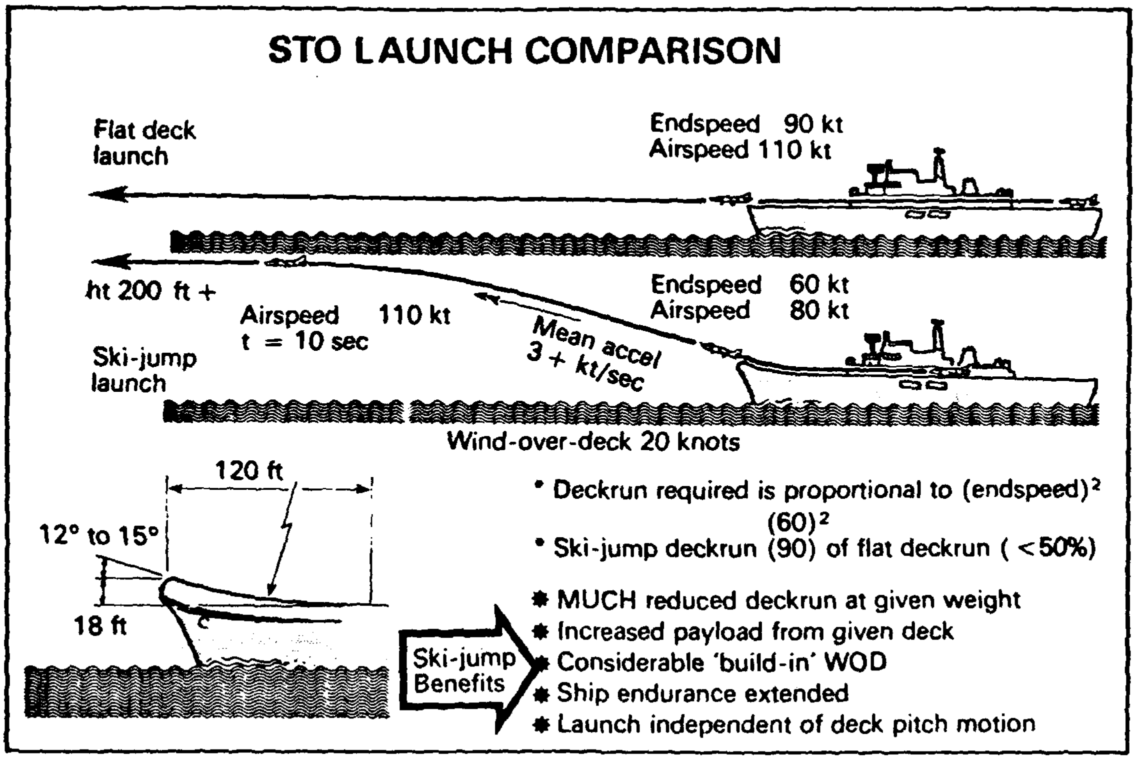
# DESIGN 698-409 ON DDV-2

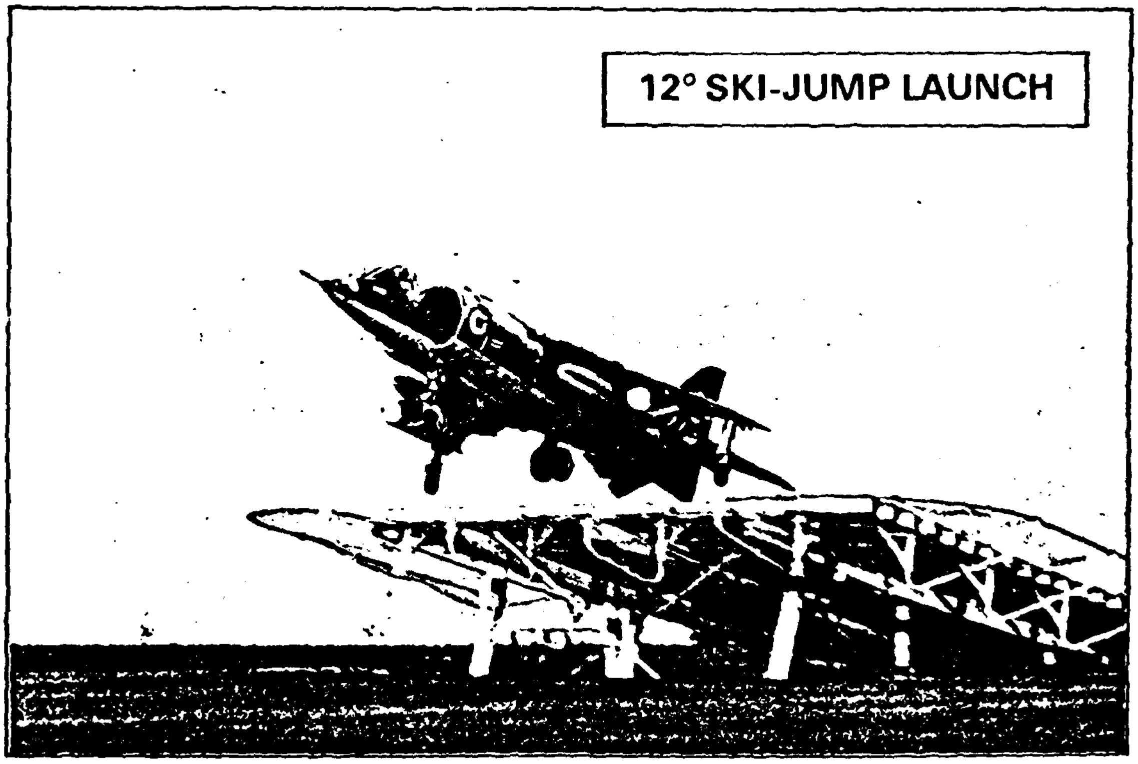



FLIGHT DECK

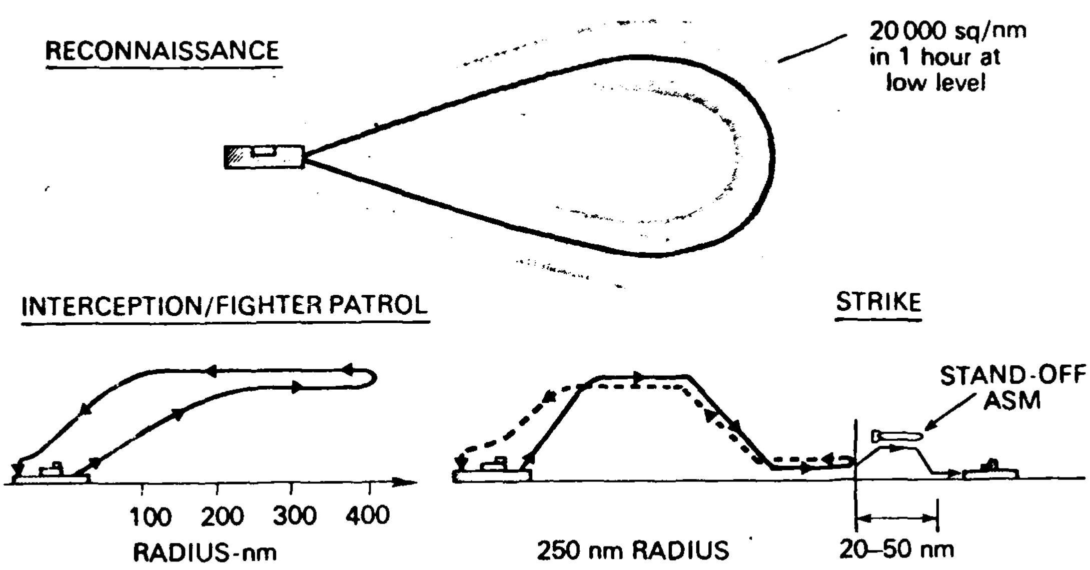



APPROXIMATE HANGAR OUTLINE FROM DATA AVAILABLE 3/8/79

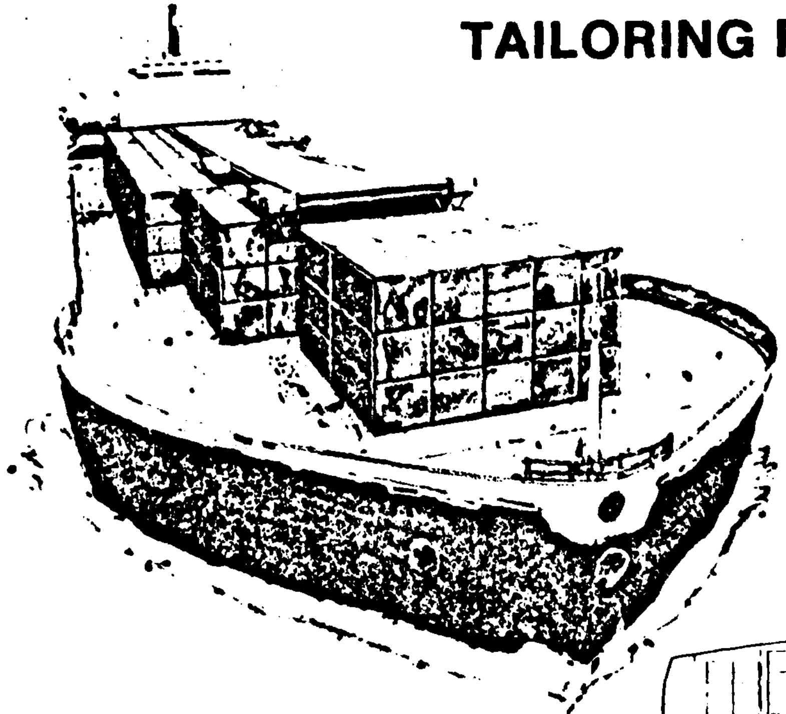

STO LAUNCH COMPARISON
Flat deck launch
Endspeed 90 kt
Airspeed 110 kt
ht 200 ft +
Airspeed 110 kt
t = 10 sec
Mean accel 3 + kt/sec
Endspeed 60 kt
Airspeed 80 kt
Ski-jump launch
Wind-over-deck 20 knots
120 ft
12° to 15°
18 ft
• Deckrun required is proportional to (endspeed)²
• Ski-jump deckrun (60)² / (90) of flat deckrun ( <50%)
Ski-jump Benefits
✱ MUCH reduced deckrun at given weight
✱ Increased payload from given deck
✱ Considerable 'build-in' WOD
✱ Ship endurance extended
✱ Launch independent of deck pitch motion


12° SKI-JUMP LAUNCH

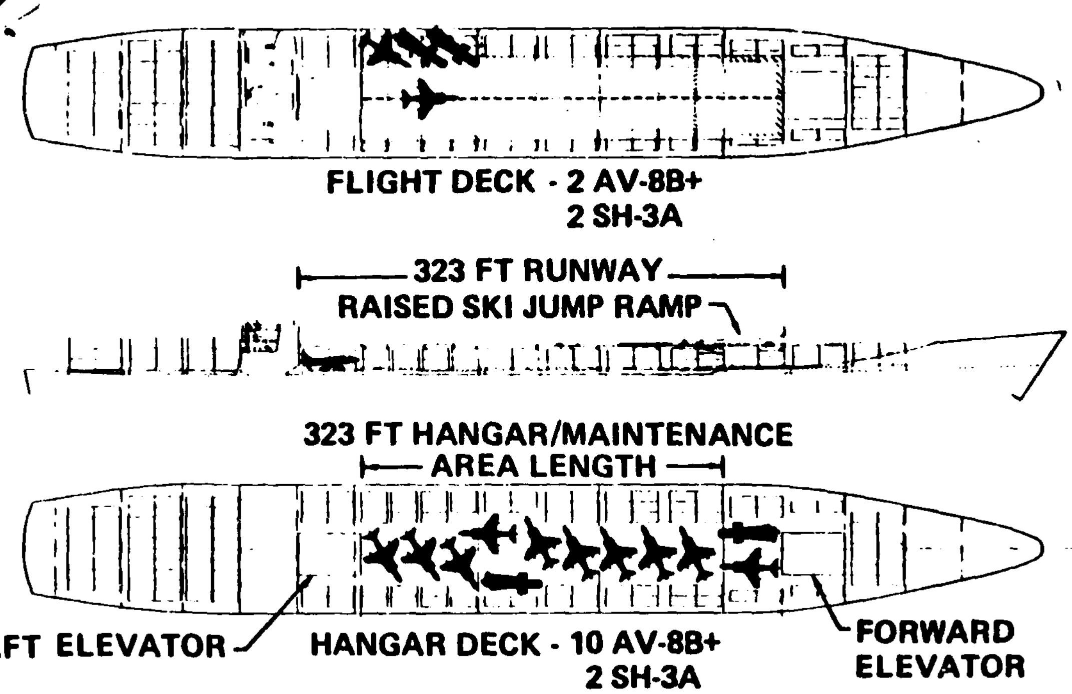
## TYPICAL HARRIER SHIPBORNE MISSIONS




# TAILORING FORCES FOR SPECIFIC MISSIONS



***AIR CAPABLE CONTAINER SHIP FOR CONVOY ESCORT DUTY OR AMPHIBIOUS ASSAULT***






33-87

# APPENDIX D

## DISTRIBUTION

Secretary of Defense
Deputy Secretary of Defense
Office of Science and Technology Policy, White House
Under Secretary of Defense for Policy
Assistant Secretary of Defense (ISA)
Deputy Under Secretary of Defense for Policy
Director, Net Assessment, OSD
Under Secretary of Defense for Research and Engineering
Principal Deputy Under Secretaries of Defense for Research and Engineering
Deputy Under Secretary for Research and Engineering (TWP)
Assistant to the Secretary of Defense (Atomic Energy)
Assistant Secretary of Defense (PA&E)
Deputy Assistant Secretary of Defense (PA&E/GPP)
Chairman, Joint Chiefs of Staff
Director, Joint Staff
Director, J-5
Director, $C^3S$
Members, Defense Science Board
Senior Consultants, Defense Science Board
Members, Defense Science Board Task Force on Surface Ship Vulnerability

Secretary of the Navy
Under Secretary of the Navy
Assistant Secretary of the Navy (RE&S)
Chief of Naval Operations
Vice Chief of Naval Operations
Commander-in-Chief, Atlantic
Commander-in-Chief, Pacific
Commander-in-Chief, Atlantic Fleet
Commander-in-Chief, Pacific Fleet
Commander-in-Chief, U.S. Naval Forces, Europe
Director, Navy Program Planning Office, OP-090
Director, Navy Command and Control, OP-094
Director, Navy Antisubmarine Warfare Programs, OP-095
Director, Navy Systems Analysis, OP-96
Director, Navy Research, Development, Test and Evaluation, OP-098
Deputy Chief of Naval Operations (Surface Warfare), OP-03
Deputy Chief of Naval Operations (Logistics), OP-04
Deputy Chief of Naval Operations (Air Warfare), OP-05
Deputy Chief of Naval Operations (Plans, Policy and Operations), OP-06
Director of Naval Intelligence, OP-009
Director of Naval Surface Combat Systems Division, OP-35
Navy V/STOL Program Coordinator, OP-05V
Chief of Naval Material
Commander, Naval Sea Systems Command
Commander, Naval Air Systems Command
Commander, Naval Ship Engineering Center
Executive Director, CNO Executive Panel, OP-00K
Naval Research Advisory Committee

Commandant, U.S. Marine Corps
Director, Plans Division, MC-PL
Director, Operations Division, MC-OTOO
Director, Requirements and Programs Division, MC-RP
Director, Aviation Plans Policy and Requirements Division, MC-AP

Secretary of the Army
Under Secretary of the Army
Assistant Secretary of the Army (RD&A)
Chief of Staff
Vice Chief of Staff
Deputy Chief of Staff for Operations and Plans, DAMO-ZA
Deputy Chief of Staff for Research, Development and Acquisition, DAMA-ZA
Aviation Systems Division, DAMA-WSA

Secretary of the Air Force
Under Secretary of the Air Force
Assistant Secretary of the Air Force for RD&L
Chief of Staff
Vice Chief of Staff
Air Force Scientific Advisory Board, AF/NB
Deputy Chief of Staff, Plans and Readiness, AF/XO
Deputy Chief of Staff, Program and Evaluation, AF/PA
Deputy Chief of Staff, Research, Development and Acquisition, AF/RD